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PARTIAL GASTRECTOMY FOR PEPTIC ULCER

A REVIEW OF SEVENTY-FOUR OPERATIONS

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FOR many years the operative procedure at the Henry Ford Hospital for peptic ulcer, apart from perforation, was limited to gastroenterostomy. Our results in general were good so far as immediate benefit was concerned, but many of these patients continued to have recurring attacks of gastric distress which limited their activity and in some instances led to a state of chronic invalidism. Marginal ulcer, the *bête noire* of the gastric surgeon, has been in our experience a rare sequela of gastroenterostomy. We believe that freedom from this and other serious complications has been due to following the operative technique taught to one of us (R. D. M.) by Finney.[1] This procedure employs the Halsted[2] principles of no crushing clamps, a minimum of catgut sutures, and the use of fine silk on atraumatic needles for the approximation of the serosal and submucosal coats. Our experience with gastroenterostomy in the treatment of peptic ulcer agrees with that of other observers in that the best results are obtained in long-standing cases of pyloric ulcer with organic stricture and definite maintained gastric retention which does not yield to conservative treatment. Gastroenterostomy is not satisfactory in the treatment of peptic ulcer when pyloric obstruction is intermittent, since this indicates that the blockage is due to the edema of pronounced hyperacidity with accompanying gastritis and duodenitis.

Dissatisfaction with the end results of gastroenterostomy led us into a brief trial of the so-called physiologic operations on the pylorus. Of these, the Finney pyloroplasty[3] is best because it is more radical than the limited pyloroplasty of the Heineke-Mikulicz or Horsley type.

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We have had no experience with direct gastroduodenostomy as sponsored by von Haberer[4] in Germany and Wilkie[5] in Scotland because results, except in the hands of the sponsors, have not been entirely satisfactory. The chief difficulty, as Wilkie has pointed out, has been in the failure to secure adequate mobilization of the duodenum, a point that has been so frequently stressed by Finney.[6] However, even in the European strongholds of this operation, the tendency has been to abandon it in favor of partial gastrectomy. Wilkie, just before his untimely death, had given up gastroduodenostomy because of the high incidence of marginal ulcers that appeared in his patients whose cases were followed over a period of years.

Beginning with pylorectomy, we have gradually extended this operation until our present-day operation of partial gastrectomy implies removal of from two-thirds to three-quarters of the stomach. This shift to the left, to borrow the phraseology of Connell,[7] has not been accepted without some misgivings. The surgeon who advises such an extensive operative procedure as partial gastrectomy for such a small lesion as duodenal ulcer must believe wholeheartedly in the operation. His beliefs must be founded on facts, preferably drawn from his own observations and experiences. It was on this basis that our decision to continue with partial gastrectomy as the operation of choice for peptic ulcer was formed.

The patient who faces a formidable operation has two questions foremost in his mind. First, what are my chances of surviving the operation; and second, do I have a reasonable chance of being relieved of my present distress? To the former question, we reply that the mortality rate during the past five years has been 5.3 per cent and that the last thirty-four consecutive ulcer patients who were submitted to partial gastrectomy have all survived; and to the latter question we reply that a satisfactory result has been obtained in approximately 90 per cent of the cases.

The material for this study was taken from the records of the Henry Ford Hospital and includes the case histories of seventy-four consecutive patients with partial gastrectomies performed during the approximately five-year period, Jan. 1, 1934, to March 1, 1939.

Age Distribution.—The youngest patient in the group studied was aged 22 years, and the oldest was aged 67 years. The average age of 44.7 years is higher than is usually given for ulcer patients, since the average patient had been a victim of peptic ulcer 7.5 years before submitting to operation. The age by decades is shown in Table I in which again the advanced age of the patient is emphasized, for 70 per cent of them were over 40 years old and 35 per cent were over 50.

Sex Distribution.—Males outnumbered females in the proportion of nine to one. The high incidence of ulcers in males brings out the great

TABLE I

AGE DISTRIBUTION

DECADE	AGE	NUMBER OF CASES	PERCENTAGE
3rd	20-29	4	5.4
4th	30-39	19	25.7
5th	40-49	25	33.8
6th	50-59	18	24.3
7th	60-69	8	10.8
	Total	74	100.0

Youngest patient, 22 years; oldest, 67 years; average, 44.7 years.

difference in the daily life of the sexes and the excessive stress and strain to which men are subjected as compared with women. Most will agree that this is an important etiological factor in the production of ulcer, and certainly these figures would tend to substantiate this opinion.

Race Distribution.—Over 90 per cent of the patients were white, and, since in this area the colored population is 7.2 per cent of the total, there is apparently no racial immunity.

TABLE II

OCCUPATION

GROUP	NUMBER OF PATIENTS	PERCENTAGE
Laborer	40	54.2
"White-collar"	15	20.2
Executive	12	16.2
Professional	7	9.4
Total	74	100.0

Occupation.—Table II shows the division of these patients according to occupation. The relatively high proportion of patients in the "executive" and "professional" groups again brings up consideration of stress and strain as important etiological factors. These two groups, together with the "white-collar" group, almost equal the number of the laboring group, although they are far outnumbered in the general population.

CLINICAL FEATURES

The subjective symptoms of peptic ulcer are characteristic and are of great diagnostic value.

TABLE III

LOCATION AND CHARACTER OF PAIN

Pain		85.2
Epigastric	78.4	
Not located	6.8	
Burning		14.8
Fullness		13.6
Gnawing		10.8
Not characterized		45.9
No pain		14.8

All figures indicate percentages.

Pain.—Pain was by far the most constant symptom; 85 per cent of the patients had this complaint. Table III outlines the details of this complaint. Thirty-five per cent had no regularity in the time of occurrence of the pain in relation to meals. Forty-nine per cent had pain from one to three hours after eating. Eleven per cent had pain less than one hour, and five per cent three hours, after eating. Only 17.5 per cent of the patients complained of night pain.

Nausea and Vomiting.—Nausea and vomiting was described as frequent by 28.5 per cent of patients; by 31 per cent as occasional; and by 11 per cent as rare. Thirty-nine per cent had no nausea or vomiting. Eighteen patients, or 24 per cent, noticed blood in the vomitus, and 30 per cent noticed blood in the stool.

Weight Loss.—This was not a prominent feature, since it occurred in only 27 per cent of these patients. However, the average loss was 21 pounds in six months. Apparently the weight loss was either very pronounced or did not occur.

Anemia was noted in only 36.5 per cent of the patients.

Physical findings are of little help in establishing the diagnosis of peptic ulcer and are of much less significance than the history and symptoms. Only 8 per cent of the patients showed general debility. Thirty-six per cent were recorded as showing pallor; 42 per cent had tenderness in the epigastrium, and only 13 per cent had more than slight tenderness. Eight per cent had muscle spasm. Eighteen per cent showed evidence of sinus disease. This is a significant figure and bears with the contention that sinus infection may be important as a focus of infection in the production of an ulcer. The average blood count was 4,200,000, with hemoglobin, 81 per cent. The hemoglobin and urinary findings were relatively unimportant, over 86 per cent being entirely normal.

Gastric Analysis.—As generally recognized, gastric analysis findings usually are not of importance or value in establishing the diagnosis of uncomplicated peptic ulcer. However, in the diagnosis of early pyloric obstruction, the overnight retention of food in the stomach confirms the significance of the six-hour barium retention in the stomach. In the second place, knowledge of the general level of free acidity in a patient with peptic ulcer is essential in the previous medical management, first, because it aids in determining the amount of alkali indicated, and, second, in the case of gastric ulcers, if a marked subacidity is found, because it is one point suggesting that the possibility of a malignant type of ulcer should be kept in mind especially.

The well-known terminal rise of free acidity was noted in a number of the duodenal patients, although many of them had a free acidity within normal limits. It might be of interest to note that all of the duodenal patients in this group who exhibited a definite hyperacidity obtained excellent results from partial gastrectomy.

TABLE IV

ROENTGENOGRAMS

DIAGNOSIS	NUMBER OF PATIENTS	PERCENTAGE
Duodenal ulcer	42	56.80
Gastric ulcer	19	25.70
Narrowed or deformed antrum	5	6.70
Marginal ulcer	3	4.05
Gastrojejunal ulcer	1	1.35
Jejunal ulcer	1	1.35
Negative	1	1.35
Not recorded	2	2.70
Total	74	100.00

X-Ray Examination.—Table IV shows the results of the six-hour and immediate x-ray examination of the stomach. A definite localized diagnosis was made in almost 90 per cent of these patients. The diagnosis was qualified in only five patients. Only one patient was entirely negative to x-ray. The two not recorded were patients with hemorrhage. This record shows very clearly the importance and accuracy of the x-ray diagnosis. The necessity of a repeated examination whenever there is any question about the certainty of the x-ray findings is generally recognized.

TABLE V

DURATION OF SYMPTOMS BEFORE OPERATION

LENGTH OF TIME	NUMBER OF CASES	PERCENTAGE
Less than 6 months	8	10.8
6 mo. to 2 years	15	20.4
2 yr. to 5 yr.	9	12.2
Over 5 years	42	56.6

Longest period, 29 years; shortest, 2 weeks (bleeding ulcer); average, 7.5 years.

Duration of Symptoms Before Operation.—A study of Table V serves to emphasize our attitude toward operation, for here it is shown that the average patient suffered from ulcer symptoms for 7.5 years before being subjected to operation. Two-thirds of the patients had characteristic remissions of their ulcers in periods varying from one month to seven years with an average remission period of six months. Despite the patients' being subjects of a chronic annoying condition, the actual period of disability before operation was relatively short, averaging only twenty-four days for the group and ranging from one day in a bleeding ulcer patient to six months.

Selection of Patients for Operation.—Ulcer patients become candidates for partial gastrectomy only when adequate medical treatment has failed. All the patients in this series were subjected to operation only after conference between one of us and Dr. John Mateer or Dr. James Baltz of our Gastroenterological Division. The following are our definite indications for operation: (1) Cicatricial pyloric obstruction, (2) perforating type of ulcer, usually into the head of the pancreas, (3) as a lifesaving measure in persisting acute hemorrhage, (4) history of re-

peated hemorrhages, (5) suspected malignant type of gastric ulcer, (6) gastrojejunal ulcer, and (7) recurrent ulcer activity after comprehensive and adequate medical treatment.

There are the following *relative* indications: viz., (1) patients in the lower economic group who cannot afford financially to follow out medical treatment properly and to face, then, possible subsequent surgical treatment; (2) patients whose intelligence quotients will not permit them to follow a medical program of therapy accurately; and (3) patients with a major type of nervous problem which is likely to interfere with successful medical treatment.

Anesthetic.—During the past year, spinal anesthesia has been used almost exclusively. Nupercaine administered by the Jones[8] technique provides adequate anesthesia lasting well over two hours. Blood pressure is more readily maintained at normal levels, and there is less nausea and vomiting with dilute solution of nupercaine, 1:1,600, than with the higher concentrated spinal anesthetic agents. Furthermore, it has not been found necessary to augment the spinal nupercaine with splanchnic injections. The calm, peaceful condition of the spinal anesthetic patients both in the immediate postoperative period and on the following day is in marked contrast to the usual postanesthetic condition of the patient who has had a general anesthetic. Chest complications are especially serious after general anesthesia; pulmonary affections are definitely less after spinal anesthesia, although atelectasis is just as frequent. It is significant to note that in Table VI there were no deaths in

TABLE VI

ANESTHETICS

AGENT	NUMBER OF CASES	PERCENTAGE	DEATHS
Ethylene and ether	56	75.65	4
Ethylene	4	5.40	0
Spinal	14	18.95	0
Total	74	100.00	4

the patients to whom spinal anesthesia was administered. The group considered in Table VI is small, but we have now performed forty consecutive partial gastrectomies under spinal anesthesia, with only one death, and that not due in any measure to the anesthetic agent.

Type of Operation Performed.—In the evolution of the operation of partial gastrectomy as developed by the authors, there has been a gradual trend toward more radical operations until now we feel that it is necessary to remove from two-thirds to three-fourths of the stomach in order to obtain the best results. The type of operation has changed too, as indicated in Table VII, from the Billroth II[9] to the Reichel-Polya,[9] and more recently to the Hofmeister-Finsterer[9] technique. The latter operation is now regularly performed because we consider that the valve formed by closing the upper end of the sectioned stomach and

TABLE VII

TYPE OF OPERATION

	NUMBER OF CASES	PERCENTAGE	COMPLICATIONS	DEATHS
Polya	60	81.10	19	4
Finsterer	7	9.50	3	0
Billroth II	5	6.70	1	0
Subtotal gastrectomy	1	1.35	1	0
Sleeve resection	1	1.35	0	0

anastomosing only the lower portion is of definite value in deflecting the upper intestinal contents past the stoma rather than cascading it into the stomach, as occurs with the Reichel-Polya operation. This impression has been confirmed on many occasions by noting that there is a great deal less bile aspirated by the continuous suction tube when the Hofmeister-Finsterer technique is employed. It has also been our experience that this valve formation delays the appearance of bile in the suction tube by at least twenty-four hours, for with the Reichel-Polya operation bile usually appears on the second postoperative day, while with the Hofmeister-Finsterer modification, bile is often not present until the third postoperative day. We believe that the first bile tends to be deflected along the jejunum past the gastric stoma and that bile appears in the stomach only when the full flow returns. The appearance of the bile in the gastric suction tube after partial gastrectomy is a welcome sign indicating that all is well with the duodenal closure, for we have come to believe that duodenal blowouts are caused more by obstruction between the duodenum and the gastric stoma than by faulty technique in closure of the duodenal stump. We have also noted that, since adopting the Hofmeister-Finsterer technique, our patients have not complained of occasional regurgitations of bile, a complication which not infrequently occurs during the convalescence following the Reichel-Polya operation. While only seven of the patients included in this study were subjected to the Hofmeister-Finsterer technique, the foregoing impressions are based upon an experience of twenty operations of this type. We favor the retrocolic, isoperistaltic plan of gastrojejunal anastomosis, using only just enough jejunum to reinforce the closed upper portion of the stomach without distortion of the intestine. Care is exercised to place the anastomosis in the infracolic compartment to avoid constriction of the efferent loop of the jejunum.

Pathologic Diagnosis.—Table VIII records Dr. Frank Hartman's diagnosis of the resected specimens. Duodenal ulcers outnumber gastric ulcers nearly two to one in this series. This is due partly to the much greater incidence of duodenal ulcer, partly to the greater incidence of repeated recurrences and chronicity in duodenal ulcer, and, finally, to the fact that duodenal ulcer is more likely to cause pyloric obstruction either reflexly by developing inflammatory edema or by contracture de-

TABLE VIII

PATHOLOGIC DIAGNOSIS

	NUMBER OF CASES	PERCENTAGE
Gastric ulcer	18	24.4
Gastric ulcer with gastritis	4	5.4
Total	22	29.8
Duodenal ulcer	32	43.3
Duodenal ulcer with gastritis	15	20.3
Total	47	63.0
Carcinoma	5	6.6
Total	74	100.0

formity than is gastric ulcer. On the other hand, a gastric ulcer definitely is potentially more dangerous to life than a duodenal ulcer because of the tendency to malignant degeneration. In our small series, five, or 18.5 per cent, of the twenty-seven gastric ulcers showed malignant changes on microscopic examination. On the basis of these findings alone, the importance of recommending operation for all patients with intractable gastric ulcers must be obvious. It can be reasonably anticipated that the probability of cure by operation for gastric carcinoma in the subclinical stage must be excellent when compared with the very discouraging results obtained by gastric resection in the usual patients with stomach cancer who come to the surgeon. Worthy of comment also is the number of cases of gastritis, especially in association with duodenal ulcer, which in our series approximated 50 per cent. Undoubtedly, the well-being of the patient after partial gastrectomy may be attributed, in part at least, to removal of diseased gastric mucosa. It is not alone freedom from annoying pain, but also relief from chronic dyspepsia, that enables many of these semi-invalids to resume their normal activities after operation. This point, so well stressed by European observers, is so infrequently discussed in this country that some authors, attempting to discredit partial gastrectomies for ulcer, have suggested that peptic ulcer is not a comparable condition on the two continents.

Postoperative Complications.—The number of postoperative complications has steadily decreased with increased experience in the management of these cases. The use of the nasal catheter with constant suction has removed all anxiety regarding leakage at the anastomotic stoma. When the amount of drainage removed from the stomach is measured, the relief of tension in the suture line can be readily appreciated. In our experience, the employment of the indwelling stomach tube has been the greatest single factor in reducing the mortality and morbidity of gastric surgery. It is our practice to leave the tube in the stomach for five days. This allows patients to swallow frequently small amounts of water for which they are very grateful, and at the same time it pre-

vents any collection of fluid in the stomach. The various complications as they occurred in the patients of this series are tabulated in Tables IX and X. Two tables have been compiled in order to demonstrate that

TABLE IX

EARLY COMPLICATIONS OF OPERATION

	NUMBER OF PATIENTS	PERCENTAGE OF TOTAL
Atelectasis	13	17.5
Ileus	12	16.2
Shock	7	9.5
Pneumonia	5	6.8
Peritonitis	4 (4 fatal)	5.4
Hemorrhage	3	4.05
Pulmonary edema	1	1.35
Cardiac Dilatation	1	1.35
Fibrillation	1	1.35

Total number of cases with early complications, 20

TABLE X

LATE COMPLICATIONS OF OPERATION

	NUMBER OF PATIENTS	PERCENTAGE
Obstruction	8	10.80
Abscess	3	4.05
Superficial infection	2	2.70
Duodenal fistula	2	2.70
Embolism	2	2.70
Evisceration	2	2.70
Superficial separation	2	2.70
Hypostatic pneumonia	1	1.35

Total number of cases showing late complications, 18.

early complications are by far the more serious, for all the deaths occurred in patients whose complications developed immediately after operation; those whose complications developed later in the postoperative period were all able to weather the storm. The most frequent complication was atelectasis which occurred in thirteen of our patients (17.5 per cent), with no fatalities. This condition is just as common after spinal as after general anesthesia. Ileus developed in twelve patients (16.2 per cent), all of whom recovered. The use of spinal anesthesia has decidedly reduced the frequency of this complication. Shock appeared in seven patients, 9.5 per cent of the series, but since we have adopted routine intravenous glucose and blood transfusions during the course of the operation, we have had not a single case of shock.

Leakage of bile from the insecurely closed duodenal stump or from injury to the common bile duct was the most serious of all complications because of the development of bile peritonitis from obstruction and perforation of the jejunum proximal to the gastrojejunal anastomotic site. There were two more patients who developed duodenal fistula as a late complication, but they both recovered.

Cause of Death.—All four deaths in this series were caused by peritonitis. Bile peritonitis occurred in three instances, twice from a leaking duodenal stump and once from injury to the common bile duct. The remaining death resulted from kinking obstruction and eventual perforation of the jejunum proximal to the gastrojejunal anastomotic site. It is instructive to note that three of the four deaths occurred in patients operated upon because of intractable hemorrhages, and that, in all but one patient, the factor determining the fatal issue was technical difficulty in closing the duodenal stump, because the ulcer had penetrated into the head of the pancreas. These findings indicate that Finsterer's suggestion of sectioning the stomach proximal to the pylorus in difficult cases might be adopted with profit.

TABLE XI

FOLLOW-UP

	NUMBER OF CASES	PERCENTAGE
Less than 6 mo.	22	31.4
6 mo. to 1 yr.	11	15.7
1 yr. to 2 yr.	11	15.7
2 yr. to 5 yr.	26	37.2
Died	4	
Total	74	100.0

Results of Operations.—Some idea of the end results of partial gastrectomy may be obtained from a study of Table XI. Our follow-up has been relatively effective, for approximately one-half of the patients in the series were followed for more than one year subsequent to operation, and one-third of them for from two to five years. Actually, there were very few untraced patients, for one-half of those in the group of 31.4 per cent who were followed less than six months were operated on so recently that they fell into the classification.

The average period of restricted activity after leaving the hospital was only 1.3 months. Less than one-half of these patients, despite advice, remained on a restricted diet after six months. The diets of the remainder were only moderately restricted. Marginal ulcer, proved by x-ray, developed in three patients, and in an equal number it was suspected, but this sequela occurred only in those patients in whom limited resection had been performed. Over 40 per cent gained greatly in weight, and practically all the rest gained slightly. Including the patients with suspected and proved marginal ulcer, 10.8 per cent still have some gastric distress, but in most instances this is only slight and readily controlled by alkaline or food.

A detailed classification of the end results is tabulated in Table XII. There it is shown that approximately 75 per cent of the patients had good or excellent results.

A patient was classified as having an excellent result if he was satisfied and if he had no complaints, no restriction of activity, and only

TABLE XII

END RESULTS

	NUMBER OF CASES	PERCENTAGE
Excellent	34	48.6
Good	21	30.0
Fair	6	4.2
Poor	3	8.6
Not classified	6	8.6
Died	4	
Total	74	100.0

slight restriction in diet. A single complaint such as occasional distress or the necessity for frequent meals was enough to place an otherwise excellent result into the "good" classification. "Fair" indicates that the patient was improved over his preoperative condition but still had some complaints, enough to consider the operation not entirely satisfactory. "Poor" means practically no improvement.

SUMMARY

1. A report is presented of seventy-four consecutive partial gastrectomies for peptic ulcer performed at the Henry Ford Hospital during the five-year period, 1934 to 1939 inclusive.

2. The mortality for this group was 5.3 per cent, and all deaths were due to peritonitis. There has not been a fatality among the last thirty-four patients in the series.

3. The males outnumbered females nine to one.

4. Over one-half of the patients had submitted to previous operations on the gastrointestinal tract.

5. Pain, nausea, and vomiting were the most constant symptoms of ulcer, being present in 85.2 per cent and 70.2 per cent of the patients, respectively.

6. Roentgenograms were the greatest single aid to diagnosis. Positive findings corroborated at operation were recorded in over 90 per cent of the cases.

7. The ratio of duodenal to gastric ulcer was two to one, whereas the ratio in our perforated ulcer series[10] was three to one.

8. One patient of the four who died, died after the development of early postoperative complications; all survived late complications.

9. The end result was excellent or good in 75 per cent of the patients.

10. Carcinoma, which was suspected neither clinically nor by the surgeon at operation, was diagnosed by the pathologist in five patients with gastric ulcer.

CONCLUSIONS

Partial gastrectomy yields such satisfactory results in the treatment of selected cases of peptic ulcer which do not respond to medical management that it is firmly established as the operative procedure of choice.

The already low mortality rate is steadily decreasing. We attribute our decrease in the mortality rate to improved operative technique resulting from increased experience and to the adoption of such measures as the use of spinal anesthetics, routine blood transfusions during operation, continuous gastric suction in the postoperative period, and administration of oxygen both during and immediately after the operation to avoid anoxia and to lessen the occurrence of pulmonary complications.

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TRANSPLEURAL ESOPHAGOGASTROSTOMY FOR CARCINOMA OF THE ESOPHAGUS AND FOR CARCINOMA OF THE CARDIAC PORTION OF THE STOMACH

A Report of Two Cases

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IN THE instances in which it can be accomplished, the resection of the lower end of the esophagus, of a portion of the cardiac end of the stomach, or of portions of both followed by esophagogastrostomy offers the most satisfactory method of dealing with carcinoma in these areas. By this procedure the growth can be extirpated and the continuity of the stomach and esophagus restored in one stage, thus avoiding the necessity for the formation of antethoracic skin tubes or for the use of rubber tubes to allow the act of swallowing to be completed. This operation should have a wide field of usefulness in view of the fact that from 33 to 50 per cent of all carcinomas of the esophagus are said to occur in the lower one-third of this organ and about 10 per cent of all those in the stomach occur at the cardia.

The approach to lesions in the cardiac end of the stomach and in the lower end of the esophagus is easier when carried out through the chest than when attempted through the abdomen. After a preliminary artificial pneumothorax has been induced, the thorax can be safely opened through an intercostal incision in the seventh or eighth interspace and an excellent exposure of the terminal third of the esophagus and diaphragm can be had (Fig. 3). When the diaphragm had been widely opened from the esophageal hiatus to the costal margin, an easy access is afforded to the entire stomach, spleen, and a portion of the liver (Fig. 4). The stomach can be readily mobilized, as can the lower half of the esophagus; and, after portions of them have been resected, the anastomosis can be completed under direct vision without having to work down in a small, dark wound (Fig. 7). If the wound edges are protected, and the pleural cavity packed off with sponges, there is little danger of empyema due to soiling the pleural cavity. Empyema follows leakage at the line of anastomosis rather than soiling at the time of operation.

The feasibility and desirability of the operation of esophagogastrostomy have long been recognized. This is evidenced by the reports in the literature dealing with the subject of esophagogastrostomy. As far back as 1895, Biondi[1] was attempting this operation on dogs. The first

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surgeon to perform the operation on a human being was Wendel,[2] who, in 1907, resected a carcinoma of the cardia and esophagus and, having closed both organs, did a lateral anastomosis between them with a modified Murphy button. His patient died in twenty-four hours of hemorrhage. In 1908 Voelcker[3] performed the first successful esophagogastrostomy on a human being after having removed a carcinoma of the cardiac end of the stomach through a transabdominal route. Good summaries of the literature can be found in articles by Bird[4] in 1939 and by Adams and Phemister[5] in 1938. The varied techniques and the ingenious schemes for performing satisfactory anastomosis of the esophagus and stomach bear witness to the fact that until very recent years no one operation as performed on human beings had been found which was satisfactory enough to recommend itself to the surgical profession. The successful case reported by Adams and Phemister[5] in 1938 after numerous laboratory experiments and the case of Marshall[6] likewise reported in 1938 have given considerable hope that now the operation is on a firmer basis than ever before. As shown in Table I, only eighteen successful esophagogastrostomies have been reported. The cases reported here bring the total number to date to twenty.

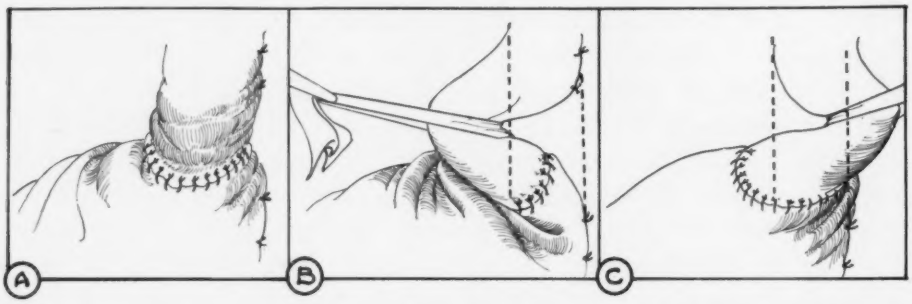

Fig. 1.—*A*, The stomach and esophagus have been sutured to the periosteum of nearby ribs so as to relieve tension on the suture line. Note the folds in esophagus and stomach indicating relaxation. *B* and *C*, With tension relieved, the anastomosed viscera can be displaced from side to side without any pull on the suture line.

The majority of the failures of the methods which have been used in the past have been due to two causes; viz., shock and leakage at the suture line. With the improved technique of operating, with better methods of anesthesia, with the recognition of the importance of preoperative pneumothorax, and with the increased use of blood transfusions, the danger from shock has practically disappeared and can now be placed at a minimum. The most potent cause for leakage at the suture line has been tension on the line of anastomosis. One has only to read the literature to be convinced of this. In the laboratory one can control leakage at will by the degree of tension on the line of suture. To ensure an intact suture line, tension must be avoided. We have attempted to obviate tension in two ways: first, by anchoring the stomach to the periosteum of a nearby rib in such a way as to

remove any pull or drag on the point of anastomosis; and second, by stitching the diaphragm well down on the stomach, rather than close to the line of suture between the stomach and the esophagus. Recently in some experimental work we have anchored both the stomach and the esophagus to the chest wall (periosteum of the rib or of a vertebral body) so that the line of anastomosis between the stomach and the esophagus can actually be displaced from side to side and from above down without the least pull on it (Fig. 1). We believe that this is a most important point in the technique and that by utilizing it one can completely avoid tension.

TABLE I

SUCCESSFUL ESOPHAGOGASTROSTOMIES REPORTED IN THE LITERATURE

SURGEON	NUMBER OF CASES	YEAR	OPERATION	PERIOD OF SURVIVAL	CAUSE OF DEATH
Voelcker[3]	1	1907	Resection of carcinoma of cardiac portion of stomach through abdominal approach	"Months"	Metastasis
Kümmel[7]	2	1909 1910	Resection of carcinoma of cardiac portion of stomach through abdominal approach	"Months"	Metastasis
Bircher[8]	1	1918	Carcinoma of cardia and lower esophagus through transabdominal approach	18 mo.	Metastasis
Gohrbandt[9]	1	1921	Carcinoma of esophagus just above cardia; abdominal approach	6 mo.	Intercurrent disease
Ohsawa[10]	8	1934	Carcinoma of the lower one-third of esophagus; transthoracic approach	No statistics given	No statistics given
Marshall[6]	1	1938	Carcinoma of terminal esophagus; transthoracic approach	Since 1938	
Adams and Phemister[5]	1	1938	Carcinoma of terminal esophagus; transthoracic approach	Since 1938	
Cattell[11]	1	1939	Carcinoma lower esophagus and stomach; two-stage combined abdominal and transpleural approach	Living 5 mo. after operation	
Garlock[13]	1	1939	Carcinoma of lower end of esophagus; transpleural approach	Living 9 mo. after operation	
Ochsner and DeBakey[12]	1	1939	Carcinoma of lower end of esophagus; transpleural approach	Living	

The rent in the diaphragm through which the stomach has been brought into the thorax must be partially closed and the edges of the diaphragm then sutured to the stomach in order to prevent herniation of the intestine through the diaphragm. When the diaphragm is sewed to the stomach, care must be taken to attach it well down toward the

greater curvature so as to place plenty of stomach in the thorax. The tendency is to stitch it too close to the anastomosis and thus create a drag on it.

In the two cases reported here, the stomach was securely anchored to the periosteum of a nearby rib, after the anastomosis had been finished, with four sutures of silk. If the stomach is lifted high enough into the thorax so that there is no tension on the anastomosis and then held at that point by stitching it to the chest wall, the danger of drag on the line of anastomosis is decreased. In one of the cases mentioned in this report, it was necessary to reopen the thorax one month after the original operation. At that time the stomach was found to be firmly adherent to the chest wall and there was no tension on the line of anastomosis. As will be seen in the following case reports, the end-to-side anastomoses between stomach and esophagus were not done aseptically, but, since there was no leakage at the suture line, the pleura was able to cope with the small amount of soiling and no empyema resulted in either case. In both instances the wound in the chest wall healed per primam.

Gastrostomy had been done in each instance weeks or months before the actual anastomosis between stomach and esophagus was performed. In spite of this the stomach could be mobilized well enough to allow a sufficient portion of it to be pulled up into the chest to reach the esophagus without tension. It would make the operation much simpler if a gastrostomy were not done as a preliminary. A jejunostomy would serve the same purpose and not interfere with the mobilization of the stomach. Though the operations were time consuming, the patients did not suffer from shock and at no time were their conditions alarming. In each instance transfusions of citrated blood were given during the operation.

Dragstedt[16] has shown the frequent occurrence of pneumonia in dogs following obstruction to the esophagus. The saliva overflows from the obstructed esophagus and is aspirated into the bronchial tree and thus gives rise to pneumonia. It also occurred to us that, if peristalsis was kept at a minimum in the esophagus for several days after the esophagogastrostomy was performed, there would be less danger of leakage at the suture line. For these two reasons the esophagus was kept empty after operation by continuous suction applied to a catheter placed in the esophagus. It was surprising how much saliva was evacuated from the esophagus in twenty-four hours. We believe that continuous suction in the esophagus after operation is of definite value. The patients were not allowed to attempt to swallow fluids until ten days after operation. The induction of a preliminary artificial pneumothorax was attempted in each case. In one it was complete, in the other only partial, due to the presence of many filmy adhesions. In each case the operation was carried out under local anesthesia down to the pleura and thereafter cyclopropane was used.

When the two patients, whose case histories are being reported, were operated upon, we had not done any experimental work on the suturing of the stomach and esophagus, but we were familiar with most of the literature dealing with esophagogastrostomy. The method in which the end of the esophagus was introduced into the stomach through a slit in its anterior wall and the stomach then pulled up around it with inverting sutures appealed to us as a method of choice. This is the method which has been advocated by Bircher,[8] Meyer,[14] Fischer,[15] and Bengolea[17] and is the method which was used in both of our cases (Fig. 2). Although there was no leakage in either instance, there were strictures in each and both patients have had to have repeated dilatations in order to be able to swallow. We felt that in Case 1 the stricture probably resulted from not having placed enough esophagus into the stomach.

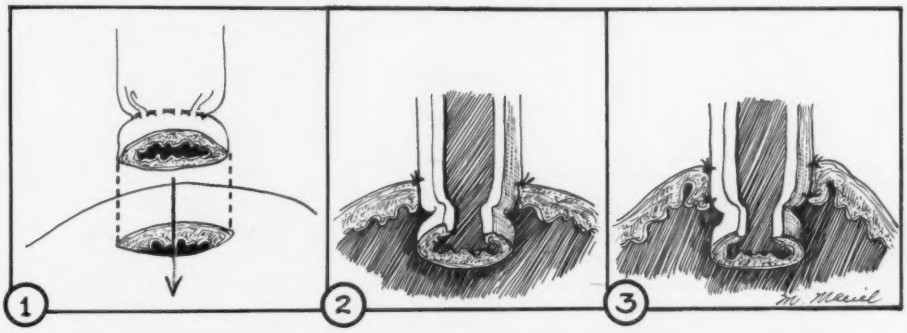

Fig. 2.—The type of anastomosis which was performed in the two reported cases. The end of the esophagus was introduced into the stomach and inverted into the latter with two rows of Lembert sutures of silk.

In Case 2, therefore, at least one inch of esophagus was introduced through the incision in the anterior wall of the stomach, nevertheless, a stricture resulted. Following our experience with strictures in these two cases, we have performed a series of experiments on animals in the laboratory and have come to feel that the above-described type of anastomosis is not desirable. It uses up an unnecessary length of esophagus; it is apt to cause early obstruction to the lumen of the esophagus by the latter's inverting into itself and to cause late strictures due to the fact that the end of the esophagus which projects into the stomach does not slough away but heals together forming a diaphragm-like stricture. The details of this experimental work will be published in a later communication.

CASE 1.—(Cincinnati General Hospital, No. 103557.) K. B., a white woman, aged 54 years, was admitted to the Cincinnati General Hospital on Sept. 15, 1938, complaining of vomiting and loss of weight. Five months before admission she had noted a slight difficulty in swallowing while she was eating a fried egg. The dysphagia had increased in severity until for the past four weeks she had been unable to swallow liquids and she had vomited everything which she attempted to swallow. She had never vomited blood. There had been a loss of twenty-four pounds in weight in the past six weeks. She had never had pain on swallowing.

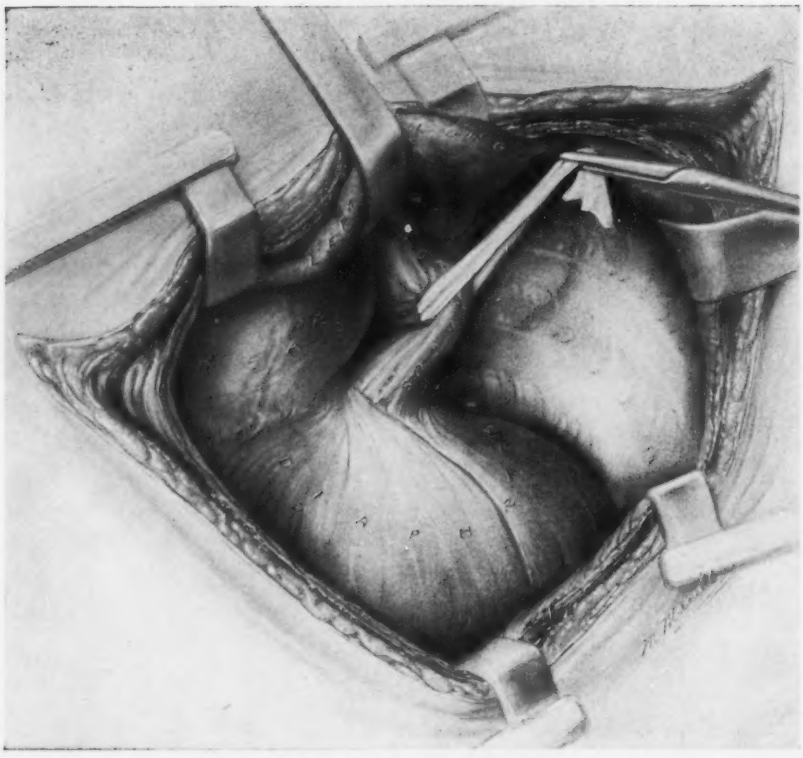

Fig. 3.—Case 1. The exposure after lung has been retracted. The esophagus has been freed and a tape passed around it.

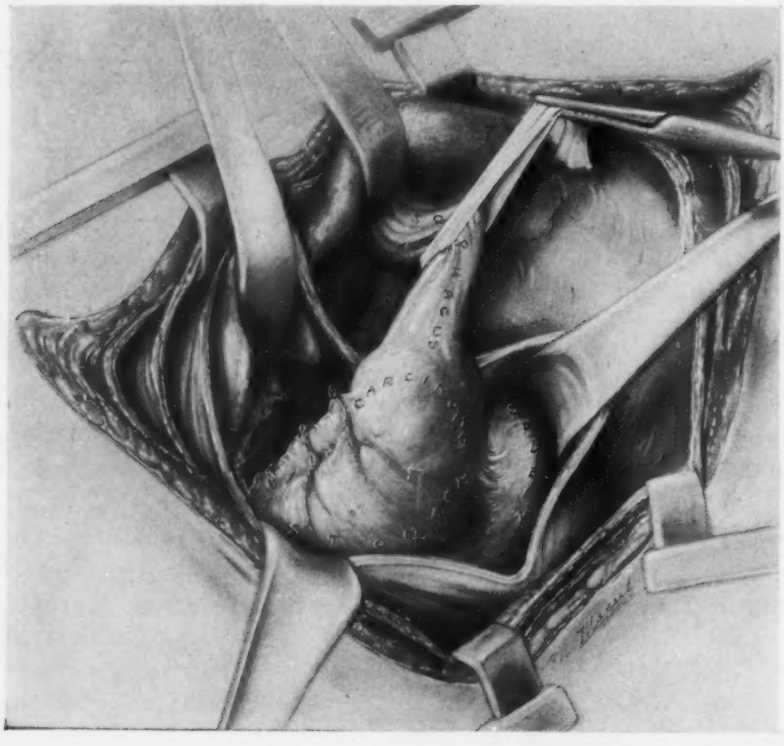

Fig. 4.—Case 1. The diaphragm has been split, the lesser curvature partially divided, and the stomach drawn up into the thorax.

Physical examination showed a thin, pale, woman who appeared to be 64 years of age, rather than her given age of 54 years. She showed evidence of marked loss of weight and was highly nervous and apprehensive. The skin was dry and wrinkled. Except for a few enlarged glands in the groins, there was no adenopathy. Her lungs were clear. The heart sounds were clear. No masses could be made out in the abdomen.

X-ray examination after ingestion of barium showed a dilatation of the esophagus down to the cardiac end of the stomach, where a smooth-walled point of obstruction was seen. The Wassermann reaction was negative. Esophagoscopy revealed a cauliflower-like growth at the junction of esophagus and stomach which was projecting into the lumen of the esophagus and involving the terminal 2 cm. of the esophagus. A biopsy from the growth showed it to be an adenocarcinoma of the stomach with considerable mitosis in many of the cells.

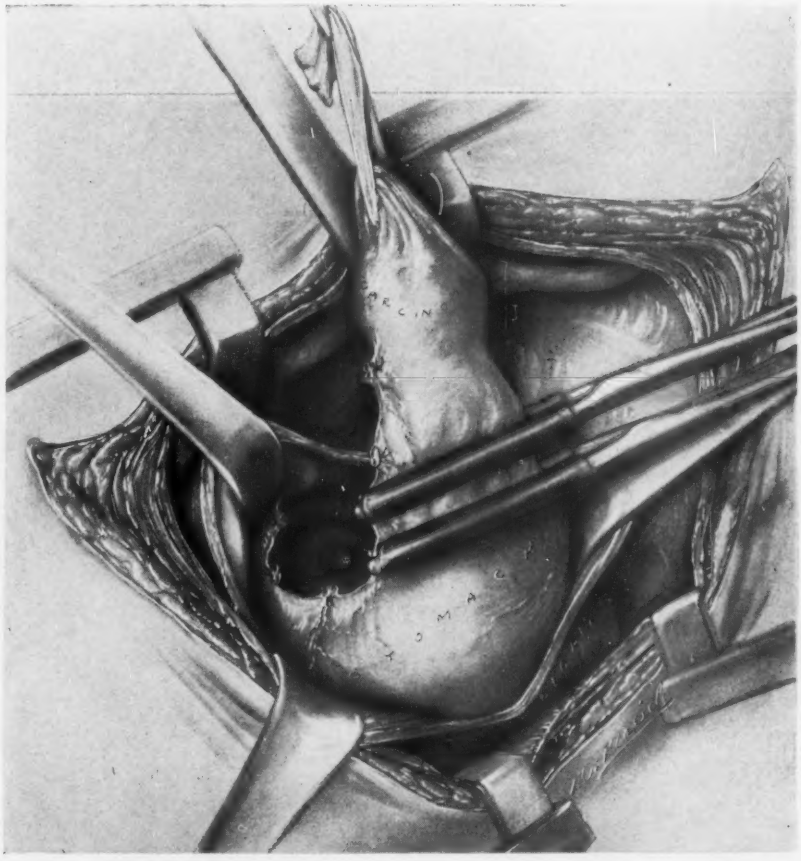

Fig. 5.—Case 1. The stomach has been freed more by dividing some of the vessels along the greater curvature and clamps have been applied beyond the growth.

On Oct. 1 a Janeway gastrostomy was done under local anesthesia. At this time a mass about 6 cm. in diameter was felt at the cardiac end of the stomach, a small gland was felt along the lesser curvature of the stomach, and the liver was found to be free of metastatic nodules. The gastrostomy functioned well and the patient gained six pounds in the first four weeks after operation. She was given a blood transfusion of 325 c.c. of citrated blood on Nov. 3 and another of 575 c.c. on Nov. 4. An attempt at the production of an artificial pneumothorax was unsuccessful owing to the presence of many adhesions between the lung and the pleura.

Under local and cyclopropane anesthesia she was operated upon on Nov. 8, 1938. A long curved incision was made down to the pleura in the seventh interspace from the midaxillary line to the midscapular line, where it was curved upward to the fourth rib. One inch of the vertebral ends of ribs VII, VI, V were resected, the pleura opened throughout the extent of the incision, and the chest spread widely open. Filmy adhesions were found binding the whole left lung to the pleura. The lower lobe of the lung was completely freed and retracted and the left phrenic nerve was crushed. The lower three inches of the esophagus were freed by sharp and blunt dissection and tapes were placed about the freed esophagus (Fig. 3). The diaphragm was now split in the direction of its fibers from the hiatus to the costal edge and the cardiac end of the stomach and esophagus dissected free. The stomach could now be partially delivered into the thorax and an excellent exposure of the stomach and lower esophagus was had. A tumor mass 5 cm. in diameter was found occupying the cardiac end of the stomach and extending into the terminal 2 cm. of the esophagus. There was one small hard gland on the lesser curvature close to the cardia,

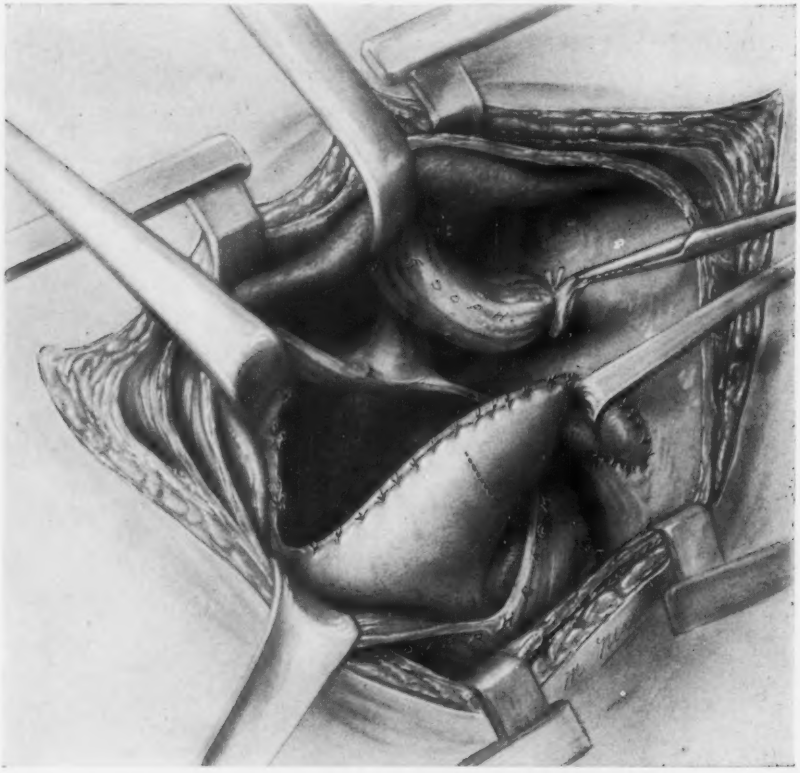

Fig. 6.—Case 1. The stomach has been closed and the growth resected. The esophagus has been closed with a purse-string suture of No. 00 plain catgut. The dotted line indicates the line of incision in the stomach (it has been made in this direction to preserve blood supply). The stomach has been anchored to the periosteum of the seventh rib.

but the liver showed no evidence of metastases. The lesser curvature was freed by dividing the left gastric artery about midway down the curvature. This allowed much more stomach to be pulled into the thorax (Fig. 4). The vessels along the greater curvature were divided between transfixion sutures of silk from the esophagus down to the middle of the greater curvature.

Payr clamps were placed across the stomach well below the lower margin of the tumor and the stomach divided between the clamps (Fig. 5). The Payr clamp was

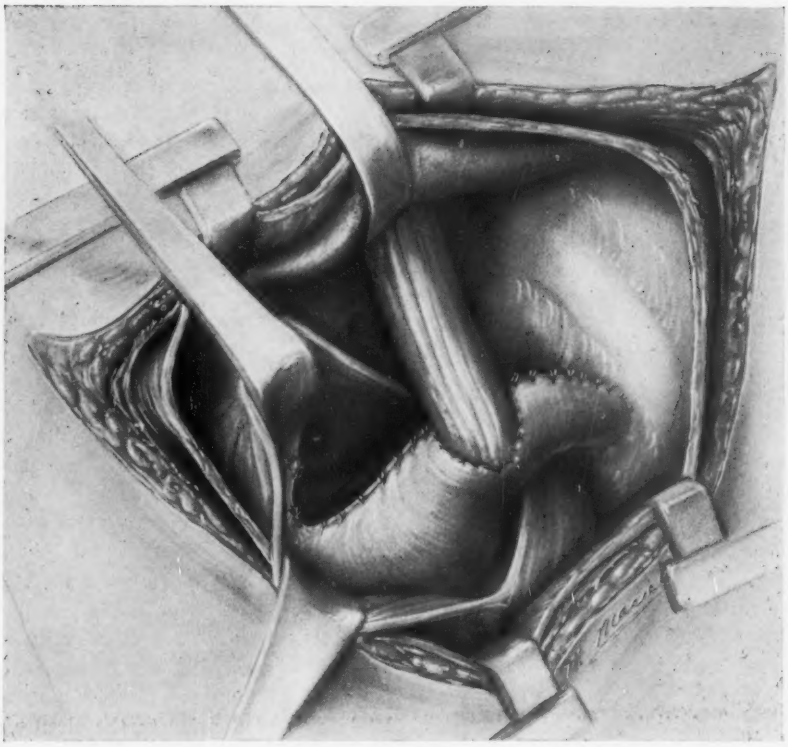

Fig. 7.—Case 1. The end of the esophagus has been introduced into the stomach through a slit and has been inverted into the stomach with two rows of Lembert sutures of silk.

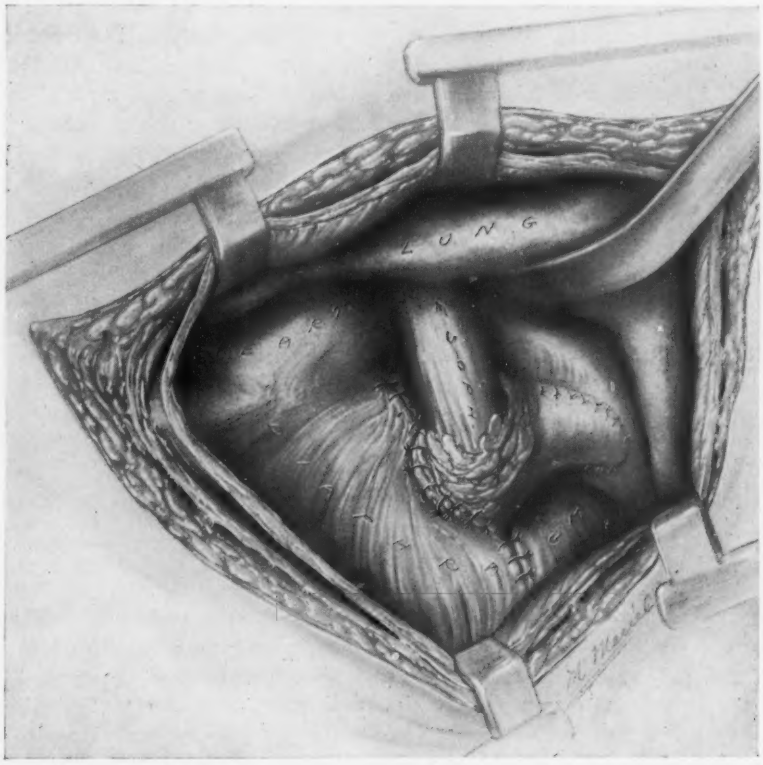

Fig. 8.—Case 1. A piece of omentum has been placed over the suture line, the diaphragm partially closed with silk, and the remainder sutured to the stomach with interrupted silk sutures.

removed and the stomach closed with a continuous through-and-through lock stitch of No. 1 chromic catgut. This line of suture was now inverted beneath a row of Halsted mattress sutures of medium silk. This left a tube of stomach which could be easily delivered into the thorax, where it was anchored to the periosteum of a rib close to the spine and with four sutures of medium silk (Fig. 6).

A purse-string suture of No. 0 plain catgut was now placed around the esophagus well above the tumor and the esophagus divided between it and a Kocher clamp. An incision 2 cm. long was made in the tube of stomach at right angles to the long axis of the stomach tube (Fig. 6). It was felt that an incision made in this direction would not interfere as much with the blood supply to the tube as would one parallel to the curvature. The lower end of the esophagus, still closed with the purse-string suture, was introduced into the stomach through this incision and the stomach united to the wall of the esophagus with two rows of Halsted mattress sutures of silk (Fig. 7). A piece of omentum was brought up and sutured over the line of anastomosis. The rent in the diaphragm was closed up to the tube of stomach with interrupted sutures of silk and the diaphragm stitched to the tube with sutures of the same material (Fig. 8). The pleural cavity was now thoroughly irrigated with a large amount of normal salt solution. Two mushroom catheters were inserted into the pleural cavity in the eighth interspace, one in the anterior axillary and one in the postaxillary lines. The ribs were pulled together with three pericostal sutures of kangaroo tendon and the muscles closed in layers with continuous suture of No. 1 chromic catgut. The skin was closed with interrupted silk with no drainage of the wound itself. The lung was completely expanded prior to the closure of the chest wall.

A transfusion of 900 c.c. of blood was given during the operation, which lasted for three hours. The operation was well tolerated, the patient's blood pressure being 100, pulse 114, and respirations 30 at the close of the operation.

After operation a nasal tube was introduced well down into the esophagus and continuous suction was maintained for ten days. At the end of that time the patient was unable to swallow liquids and continued unable to do so. X-ray and esophagoscopic examination showed the presence of a stricture at the site of anastomosis and this was unable to be penetrated either from above or from the gastrostomy below. A cystoscope was repeatedly introduced by Dr. Henry Freiberg into the stomach through the gastrostomy and the cardia visualized, but no opening could be seen or entered. It was evident that the stricture must be dealt with surgically.

On Jan. 4, 1939, two months after the first operation, the wound was reopened under local anesthesia and the anastomosis inspected. There were few adhesions about it, no evidence of recurrence and from the outside it looked perfect. However, one was unable to feel any lumen at the point of anastomosis, but only hard dense scar within the lumen of the esophagus. A metal sound was introduced through the gastrostomy opening and after considerable difficulty was pushed through the stricture into the esophagus under direct guidance. The condition of the patient was such that further maneuvers were abandoned and the wound closed. After this operation nothing passed through the stricture and attempts at swallowing a string were futile.

On Jan. 7, 1939, the wound was again reopened under local anesthesia and the anastomosis inspected. There was no change in its appearance. A longitudinal incision from above downward was made through the stricture, partly in the esophagus and partly in the stomach. The stricture was composed of very dense fibrous tissue, but no recurrence of the carcinoma could be seen. A ureteral catheter was introduced into the opening in the esophagus and pushed out of the mouth. A braided silk thread was attached to this and it was pulled down through the opening in the esophagus. A sound was passed up from the gastrostomy into the incision through the stricture, the braided silk thread attached to it and this thread pulled out through the gastrostomy opening. The braided silk string was thus pulled

through the stricture and was left in place. The incision through the stricture was now closed transversely to the long axis of esophagus and the chest closed as before.

Following this operation, dilators of increasing size were threaded on the braided silk cord and pulled through the stricture from below upwards. After a few weeks a No. 36 French dilator could be easily pulled through the stricture. The patient was then able to swallow liquids, soft foods, and small pieces of hard food. She gained ten pounds in weight. However, in spite of the fact that large-sized dilators would pass through the stricture from below upwards, the patient had periods in which swallowing was very difficult and she would occasionally vomit.

In August, 1939 (nine months after operation), she was readmitted to the Cincinnati General Hospital complaining of difficulty in swallowing, pain in the lumbar region and pain in the stomach when feedings were introduced through the gastrostomy. The cardiac end of the stomach was inspected through a cystoscope introduced through the gastrostomy and no evidence of recurrence seen. An esophagoscope was passed and a small slitlike opening seen with scar tissue piled up around it, but no recurrence was made out. X-ray examination failed to show metastases to the spine or ribs. She was fed through the gastrostomy and seemed to improve slowly for three weeks. On Aug. 21, 1939, she died suddenly.

An autopsy was performed, but no cause for death was found. No recurrences were discovered and there was no evidence of metastasis. The suture line was intact. The esophagus was dilated just above the stricture into a small sac-like segment. The stricture was nearly complete, only a tiny slitlike opening remaining. The walls of the stricture were composed of extremely hard, dense fibrous tissue. No carcinoma was present in the stricture.

Comment.—A jejunostomy rather than a Janeway gastrostomy should have been done in this case when it was found that the growth was in the cardiac end of the stomach and the lower end of the esophagus. The delivery of the stomach into the chest was certainly hindered by the gastrostomy, but even with the gastrostomy enough stomach could be pulled up to permit a satisfactory esophagogastrostomy to be done.

It was felt that there were two reasons for the occurrence of the stricture: first, that not enough esophagus was introduced into the opening in the stomach so that, when contraction during healing occurred, the short stump of esophagus pulled out of the stomach and the edges of the esophagus healed together, thus accounting for the stricture; second, that the opening in the stomach was made at right angles to the axis of the stomach, rather than parallel to it, so that when the stomach musculature contracted it tended to close the opening rather than widen it.

Apparently the cancer had been completely removed since no recurrence or metastasis was found at autopsy. If the stoma had functioned properly, the patient would have been well and probably free from her cancer for the rest of her life.

No cause was found at autopsy for this patient's death, but it must have been dependent in some way upon her stricture with consequent inanition.

An excellent exposure of the entire stomach or lower esophagus was obtained through the transpleural approach, and the anastomosis was performed more easily than it could have been by abdominal approach.

CASE 2.—Mrs. M. P. (Christian R. Holmes Hospital No. 390448), aged 58 years, was admitted to the hospital on May 8, 1939. Her present illness had begun in May, 1938, at which time she first experienced difficulty in swallowing. Within a few weeks she was unable to swallow solid foods and regurgitation after swallowing was common. In July, 1938, she was referred to a roentgenologist, who found almost a complete obstruction at the lower end of the esophagus. For two months she remained on a liquid diet and lost from twenty-five to thirty pounds in weight.

In September, 1938, an esophagoscopy was done. A constricting, ulcerative lesion was found in the lower one-third of the esophagus and a biopsy was taken. The pathologist's report was "squamous-cell carcinoma." The constriction was dilated every three or four days for several weeks to permit saliva to pass, but the esophagus would close again in a very short time. Because of her rapid loss of weight and strength, a gastrostomy was performed on Oct. 5, 1938. This procedure checked further loss of weight, but did not relieve the regurgitation of saliva.

The patient related that for two years preceding the difficulty in swallowing she had been troubled with indigestion, belching, and an occasional epigastric pain which radiated straight through to the back. When the difficulty in swallowing developed, she experienced the sensation of a lump behind her heart which could be relieved only by vomiting. She did not vomit blood and there were no black or tarry stools.

With the complete obstruction of the esophagus, constipation became so severe that she required frequent laxatives. Stagnation and fermentation of the saliva in the esophagus was one of her worst complaints and was a source of great embarrassment. She learned to regurgitate this material almost at will so that she could empty the esophagus before appearing in public. However, she could not escape the odor and taste of the fermented saliva and mucus. These alone, and not the desire to take food by mouth, were responsible for her seeking surgical aid.

The patient was an emaciated woman, very active and mentally clear. She weighed sixty-four pounds. The skin was loose and dry. The mucous membranes had good color. Other than a foul halitosis, a gastrostomy through the upper left rectus muscle, and signs of malnutrition, the examination was not remarkable.

On fluoroscopic examination a complete obstruction was demonstrated in the lower esophagus about 7 cm. from the cardia. The esophagus was greatly dilated above the obstruction and exhibited powerful peristaltic action. Barium introduced through the gastrostomy showed the fundus of the stomach to be normal. Roentgenograms of the chest and spine showed no evidence of metastases. Artificial pneumothorax was begun on the left on May 9, 1939, and after four treatments a complete collapse of the lung was effected. The esophagus was irrigated thoroughly several times a day. The patient's oral hygiene was good and with adequate care of the esophagus the halitosis and objectionable taste in the mouth largely disappeared.

Two weeks after her first pneumothorax treatment the patient was operated upon. The operation was begun under local anesthesia. An incision was made along the course of the seventh interspace up to a point two and one-half inches from the spine, where it was curved upward to the fifth rib. The incision was deepened down to the pleura and a one-inch segment of the seventh rib was resected close to the spine. Hemostasis was secured with electrocoagulation, after which the operation was continued under cyclopropane anesthesia. The pleura was opened and the chest spread widely with rib spreaders. The wound edges were carefully protected with moist towels. The lung was found to be well collapsed and free of adhesions. The terminal esophagus and aorta were easily visualized. The phrenic nerve was isolated just above the diaphragm and crushed. The loose parietal pleura over the esophagus was incised in a linear direction and continued upward into the inferior pulmonary ligament.

A tumor could be felt in the esophagus, but apparently there was no spread to the pleura or mediastinal glands. The esophagus was constricted by a dense annular growth rather than enlarged by a space-consuming mass. The tumor mass measured two inches in length and was located one and one-half inches above the diaphragm (Fig. 9). Sections later showed the lumen to have been completely obliterated. By blunt dissection, the esophagus was easily freed from the diaphragm to the arch of the aorta. In attempting to keep as much of the areolar tissue as possible with the esophagus, the right pleura was wiped too close and a small leak later developed which made it necessary to complete the operation under positive pressure anesthesia.

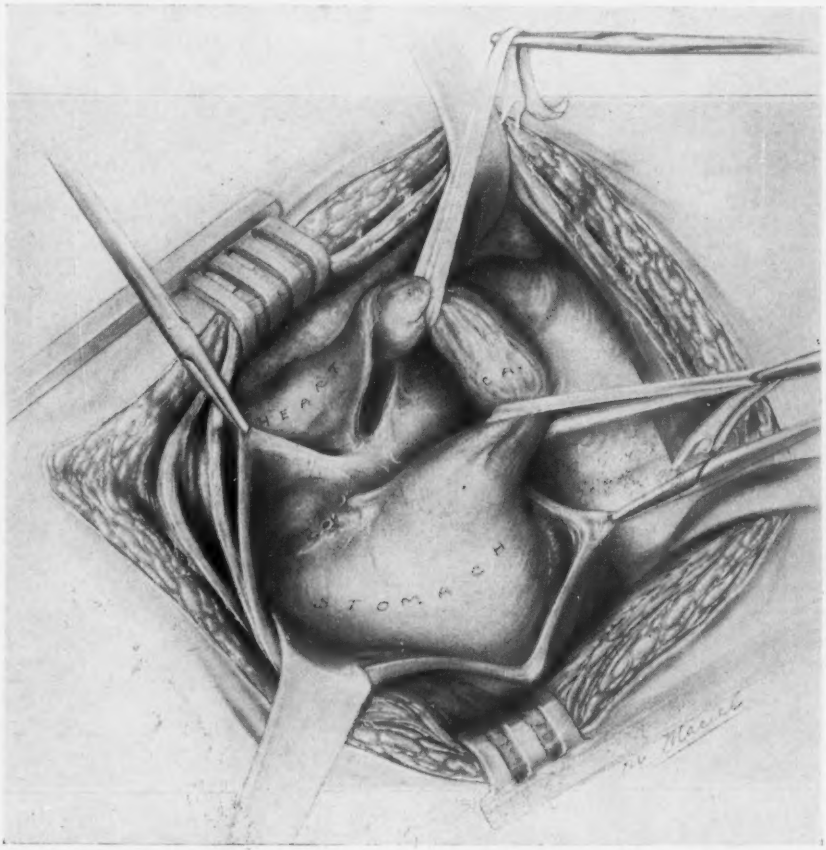

Fig. 9.—Case 2. The exposure of the carcinoma in the lower esophagus. The esophagus has been freed nearly to the aortic arch, the diaphragm opened, and part of the gastrocolic omentum divided.

An incision was made through the diaphragm radially from the esophageal hiatus to the costal margin and the diaphragm was completely freed from the esophagus. An excellent exposure of the entire stomach, spleen, and left lobe of the liver was obtained and no involved lymph glands were found along either curvature of the stomach. The liver was free from nodules. The stomach was partially mobilized by dividing the gastrosplenic, gastrophrenic ligaments, and the lateral attachments of the gastrocolic omentum. After this procedure the fundus of the stomach could readily be elevated to the level of the sixth rib posteriorly. The stomach was cut across about one inch below its junction with the esophagus, and the opening in it thus produced was closed with a continuous suture of No. 1 chromic catgut. A row of interrupted Lembert sutures of medium silk was used to invert this first line of

suture. The stomach was drawn into the chest and anchored posteriorly to the periosteum of the seventh and eighth ribs by means of four medium silk sutures.

The esophagus was tied off with a purse-string suture of catgut well above the tumor, and the esophagus cut across between this ligature and a Kocher clamp. An incision was made through the anterior wall of the stomach well up on the fundus. The end of the esophagus, still closed by the purse-string suture of catgut, was introduced into the stomach through this slit so that one inch of esophagus projected into the lumen of the stomach (Fig. 10). The stomach and esophagus were now united by interrupted Lembert sutures of medium silk. One row of sutures was used posteriorly and two rows anteriorly. The purse-string suture of catgut was removed from the end of the esophagus just before the last sutures were tied. Care was taken to insert the sutures in the long axis of the esophagus to avoid the constriction

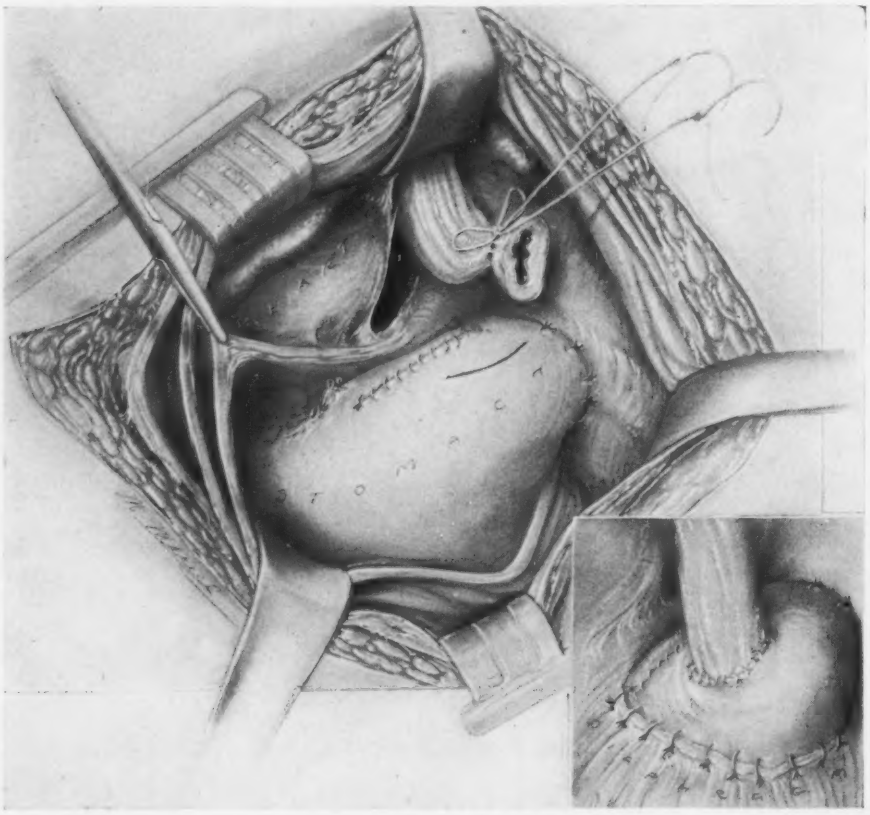

Fig. 10.—Case 2. The growth in the esophagus has been resected along with a portion of the stomach. The stomach has been closed. The solid line on the stomach shows the line of the incision in the fundus through which the end of the esophagus was introduced (contrast the direction with that in Fig. 6). The end of the esophagus has been closed with a purse-string suture of No. 00 catgut, the ends of which were left long and used to pull the esophageal stump well down into the stomach, while the latter was sutured around the esophagus. The insert shows the completed anastomosis. Note the sutures which attach the stomach to the periosteum of the seventh rib.

of the blood vessels. The line of anastomosis was almost completely covered with a tag of omentum. A stoma which would permit the introduction of almost two fingers was produced by the anastomosis. The lateral angle of the opening in the diaphragm was closed with interrupted silk sutures and the remaining edges were anchored to the stomach with interrupted sutures of the same material.

A No. 22 mushroom catheter was inserted through a stab wound in the anterior axillary line in the ninth interspace. The chest cavity was irrigated with saline

solution, and the chest wall was closed, using three kangaroo tendon sutures about the seventh and eighth ribs, continuous No. 1 chromic catgut in the superficial muscles, and fine silk in the skin. A dry dressing was applied.

The lungs were well inflated with positive pressure as air was drawn by syringe through the catheter. The catheter was then attached to a continuous Wangensteen suction apparatus. A Levin tube was inserted into the esophagus through the nose and connected to another Wangensteen suction apparatus. During the operation, the patient had received approximately 2,500 c.c. of 5 per cent glucose and 700 c.c. of citrated blood.

Convalescence was uneventful. The temperature reached 102° F. on the day following the operation and fell by lysis to normal on the fourth postoperative day. Sutures were removed from the incision on the fifth and seventh days. There was no vomiting. She was given one ounce of water by mouth every two hours on the sixth day and the amount slowly increased thereafter. The catheter was removed from the chest on the ninth day, at which time the lung was found to be fully expanded and all wounds had healed without infection.

On the eighteenth postoperative day fluoroscopy showed excellent function of the esophagus. The patient had been on a liquid diet by mouth since the tenth day after operation. At lunch on the day following the fluoroscopy the patient complained of a heavy feeling behind the stomach, had some difficulty in swallowing, and regurgitated some of her food. On the next day she could swallow liquids and soft foods without difficulty if taken slowly in small amounts. A medium-sized Tucker dilator could be drawn through the anastomosis from the gastrostomy opening without any feeling of resistance. The patient was discharged to her home on June 16, 1939. By this time she was able to take complete care of herself and prepare her own meals. She was advised to have dilatations done at weekly intervals. As long as she had the weekly dilatations of the stoma, she could swallow liquids easily and also soft foods. She neglected to return for treatment after a few weeks and by the end of August, 1939, she was having trouble in swallowing anything but a strictly liquid diet.

On Oct. 2, 1939, the patient returned for a check-up examination. Her general condition was excellent. She had gained twenty-five pounds in weight and was completely free of any signs of obstruction as far as saliva and other liquids were concerned. However, she was having trouble with any semisolid food which might contain small lumps. She then admitted it had been six weeks since she had had a dilatation. Fluoroscopy showed considerable retardation in the passage of barium through the anastomosis, only a thin trickle of barium finding its way into the stomach.

The patient was taught to dilate her own stricture with Tucker dilators which were threaded on a string and pulled through the stricture from the stomach side. She did not wear a string constantly but would swallow it at will and draw it through the gastrostomy opening with a syringe. After the dilatation the string would be removed. Under this regime she has continued to swallow liquids and soft foods easily, is feeling well, and is leading a normal life.

Comment.—The mobilization of the stomach was considerably interfered with in this case by the presence of the gastrostomy, which emphasizes again that a preliminary jejunostomy is preferable to a preliminary gastrostomy. However, a gastrostomy after the operation of esophagogastrostomy has been performed is of great value and, in fact, is essential. Immediately after operation the gastrostomy prevents the extreme dilatation of the stomach which can readily result from the swallowing of air, but the inability to belch it up through a stoma which is encroached upon by edema. It is a means of keeping the stomach

free from an accumulation of fluid which might produce an unusual strain on the suture line during retching or attempts at vomiting. It offers a means of keeping up the patient's food or fluid requirements during the ten-day postoperative period when swallowing is prohibited. If a stricture forms at the stoma, it can readily be dilated by introducing dilators through the gastrostomy as was done in this case and in Case 1. Therefore, in the future it is planned to do a preliminary jejunostomy if it is necessary to feed the patient for several days or weeks before operation, and at the end of the operation of esophagogastrostomy to do a gastrostomy through the abdominal wall.

Indications of stricture were first noted on the eighteenth day after operation. The stricture has been able to be controlled by repeated dilatations, but, if these are stopped, difficulty in swallowing soon appears.

As in Case 1 the wound in the chest wall healed per primam and there was no empyema of the pleural cavity. At the time of operation there must have been gross soiling of the pleural cavity from the stomach and from the cut end of the esophagus, but the pleural cavity seemed able to contend with this, provided all clots and blood were removed from it. A large series of operations of this type performed on animals has convinced us that the esophagus can be openly anastomosed with the stomach in the thorax without fear of empyema, provided that all foreign material is removed from the pleural cavity, that perfect hemostasis is observed, and that no leakage at the suture line occurs.

SUMMARY

1. Two additional cases of successful transpleural esophagogastrostomy are reported. One patient who was operated upon in May, 1939, is alive and apparently well. The other patient died ten months after operation and, though no cause could be found at autopsy for her death, it must have been related to a stricture at the site of anastomosis which developed after operation.

2. The type of esophagogastrostomy in which the end of the esophagus is introduced into the stomach through a slit in the latter was used in both cases herewith reported, but it is not to be recommended. Stricture followed in each of the two cases in which this type of anastomosis was performed.

3. Anchoring of the stomach and the esophagus to some portion of the bony thoracic cage after they have been anastomosed is advocated in order to relieve tension on the suture line.

4. The use of continuous suction in the esophagus after esophagogastrostomy is of advantage in relieving pressure on the suture line by removing the accumulated secretions and by keeping esophageal peristalsis at a minimum.

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THE REGULATION OF CIRCULATION IN DIFFERENT POSTURES

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IN 1913 Lindhard was able to show that the circulation rate is smaller in standing and sitting positions than in lying position. This result has been confirmed by later investigators who have obtained well-defined resting conditions involving a minimum of muscular activity and consequently almost the same O_2 consumption in the different postures.

In many cases the erect posture undoubtedly means a maximal stress put on the circulatory system. It is a well-known fact that especially young people with poor muscular tonus are inclined to circulatory insufficiency (decrease of arterial blood pressure, nausea, and collapse) while maintaining the standing position for a long time.

It has been our object of research to investigate if, in connection with the diminished cardiac output in standing position, any symptoms of circulatory insufficiency can be demonstrated also in cases where the arterial blood pressure remains normal and where no subjective signs of poor circulation are obvious.

METHODS AND RESULTS

The subject was placed on a tilting board and fixed in such a way that the different postures between +60° (head up) and –60° (head down) could be maintained without any extra muscular effort.

Fig. 1 shows the results of a typical experiment with a normal young man in good physical condition (aged 35 years; height, 188 cm.; weight, 85 kg.). The subject was tilted from horizontal to head-up position (+45°) and sixty-five minutes later back to horizontal position. One leg of the subject was partly (8 L.) inclosed in an air-filled phethysmograph. The curve of Fig. 1 shows a large increase in volume of the leg by changing from 0 to 45°. The swelling of the leg (475 c.c.) is due to an increased hydrostatic pressure in the veins and capillaries of the lowered extremities, which will bring about a filling up of blood in the vessels, especially in the veins, and a filtration of fluid through the capillary walls. The volume change due to filtration and filling up of blood is clearly demonstrated in the plethysmogram. By tilting the subject from 45 to 0°, the plethysmogram shows a steep fall, corresponding to the amount of blood poured out from the vessels (275 c.c.), while the gradual decrease in volume is due to absorption of the filtrate.

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While the oxygen consumption remains constant, the cardiac output (determined *ad modum* Grollman) shows a marked decrease (from 4.6 to 3.9 L. per minute). In the standing position* the systolic pressure is remarkably constant while the diastolic pressure is increased and consequently the pulse pressure is decreased. The pulse rate shows a sudden increase immediately after tilting from 0 to 45° and a more gradual increase during the whole period of standing; on tilting from 45 to 0°, the pulse rate suddenly drops back to the original value.

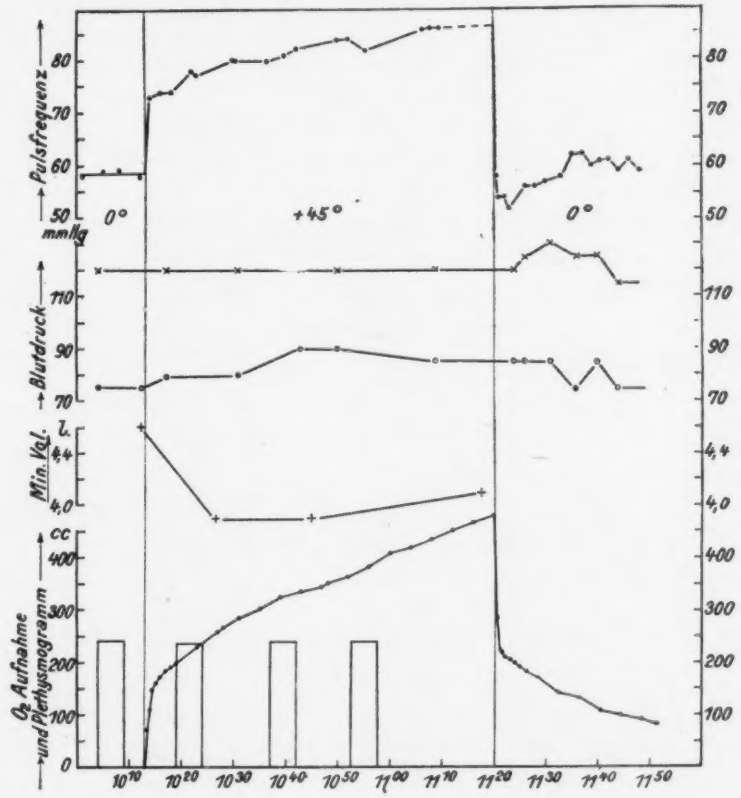

Fig. 1.—Oxygen consumption, plethysmogram, minute volume output of the heart, blood pressure, and pulse rate in horizontal position (0°) and in the head-up position (+45°). (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 214-224, 1939.)

The unchanged O_2 uptake in standing position makes it probable that the circulation rate, in spite of a lowered cardiac output, has been sufficient to secure a normal oxygen supply to the different tissues, but it does not necessarily mean that the circulation also has fulfilled the other claims laid to it for heat regulation, digestion, or renal function.

It may be of importance to remember that the arteriovenous O_2 difference of the arterial and of the mixed venous blood gives little or no information as to the oxygen utilization of the blood through a certain organ. In muscles the circulation rate is very likely adapted to the O_2

*The standing position here does not mean the normal standing position, but only a head-up position. The legs were practically hanging with relaxed muscles.

consumption and the O_2 utilization will therefore be high; in the kidneys, the intestines, and especially the skin the irrigation may be very high compared to the O_2 consumption and the venous blood leaving these organs therefore may have nearly the same O_2 content as the arterial blood. The high O_2 utilization found during muscular work may only mean a new distribution of the blood; relatively more blood is now passing through organs with a high O_2 consumption at the given rate of irrigation. In the same way the high arteriovenous O_2 difference found in shock conditions or during quiet standing does not necessarily indicate a slowing down of the circulation through all organs but may only show that, as the circulation cannot fulfill all claims laid to it, it is reduced through organs where it can be abandoned for some time without doing too much harm, that is to the skin, the intestines, and the kidneys, while the O_2 transport has to be kept up at a normal rate.

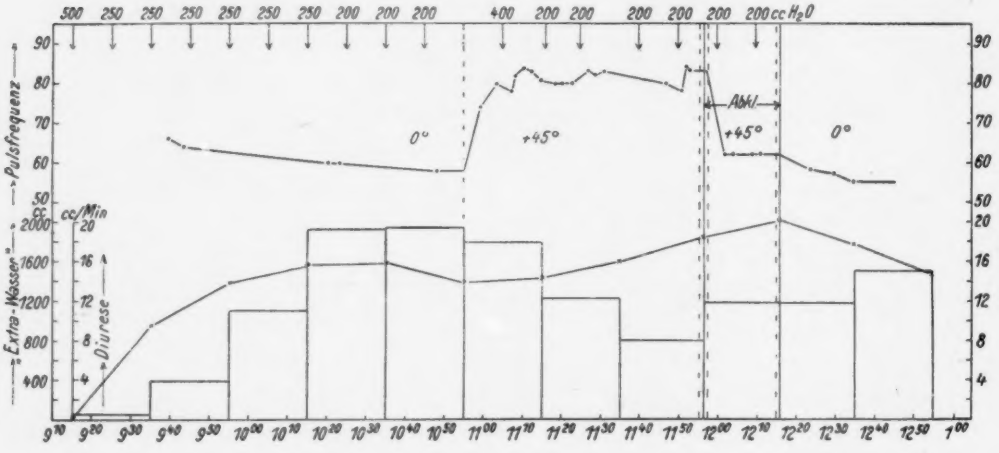

Fig. 2.—Diuresis (rectangles), extra water content of the body, and pulse rate during the drinking of water in the horizontal (0°) and in the passive standing positions (+45°), before and after (*Abkl.*) cutting off the circulation to both lower extremities by pneumatic cuffs applied while the subject was in the head-down position (–20°). Arrows indicate drinking of water. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 214-224, 1939.)

To get some information regarding circulation to the intestine in the standing position, experiments with water intake in lying and standing positions were carried out. Fig. 2 shows some results from one such experiment. The subject was placed on the tilting board and the water intake started in horizontal position. During ninety minutes he drank a total amount of 2.6 L. of water at body temperature. The diuresis went up from a value of 0.6 c.c. per minute to 20 c.c. per minute.

The subject was now tilted to standing position (45°). In spite of the fact that the water intake continued at the same rate as before, the diuresis showed a marked drop to about 8 c.c. per minute during the following fifty minutes. The subject was now tilted to head-down position (–20°) and kept there for about one minute. Two pneumatic cuffs, placed as nearly proximal around his thighs as possible, were then inflated to a pressure of 300 mm. Hg and he was tilted back to the stand-

ing position once more. During the following twenty minutes the diuresis increased to 12 c.c. per minute. Finally the subject was tilted back to horizontal position, the pressure on the cuffs was relieved, and the diuresis was measured during the next forty minutes. The last value was almost 16 c.c. per minute.

During the first period at 0°, the pulse rate slowed down to below 60, but the tilting to +45° induced a marked acceleration to 85 beats per minute. In the second period of standing the pulse rate was practically back to horizontal values again as a result of the transfer of blood from the lower extremities to the central vessels (see page 609).

In parallel experiments where the protein content of the blood plasmas was determined, a definite dilution of the plasma could be shown to take place during water drinking in horizontal position, while a marked concentration far above the original value took place in the standing position in spite of the intake of large amounts of water. Here again the second period of standing (with inflated cuffs) showed quite a different result, a pronounced dilution of the plasma.

The most probable explanation for the relatively small diuresis in the standing position seems to be that a large amount of the water remains in the intestines, due to a locally reduced circulation. That the circulation to the kidneys is reduced too was made probable by the fact that all three subjects showed signs of albuminuria after having maintained the quiet standing position for about one hour.

The circulation through the vessels of the skin, too, has other important functions besides the O_2 transport. In warm environment the skin circulation is much increased not due to higher O_2 consumption but due to increased demands on the heat-regulating mechanism. A large change in blood distribution therefore might be expected to produce a similar effect on the skin circulation as was the case on the circulation to the intestines.

It could be shown that when a subject in a warm room (35° C.) was tilted from horizontal to head-up position (45°) the skin circulation was much reduced, causing a drop in mean skin temperature of about 1° C. in one hour. At the same time the rectal temperature was increased about 0.5° C., due to the vasoconstriction in the skin.

The diminished cardiac output in quiet standing position is undoubtedly closely connected with the filling up of blood in the lower extremities. Primarily this accumulation of blood in the periphery will involve a diminished filling and a diminished pressure in the central veins and consequently a decreased return flow of blood to the heart. The effect of a lower pressure in the central veins to a certain extent can be compensated through an increase in pulse rate; that is, if the filling of the heart is more rapid during the first period of diastole than later on. The following figures will demonstrate a very close relation between posture and pulse rate.

Fig. 3 shows the changes in pulse rate of the same subject as mentioned before by tilting from 0 to +60 or –60°. In Experiments a and c the blood could freely move to and from the legs, while in Experiment b the cuffs round the thighs were inflated in the horizontal position and consequently the vascular bed in which the blood could move freely in and out was limited significantly. In Experiments a and c the pulse rate went above 80 per minute in head-up position, and in head-down position we found figures as low as 36 or 37. In Experiment b the effect of tilting was very much less pronounced.

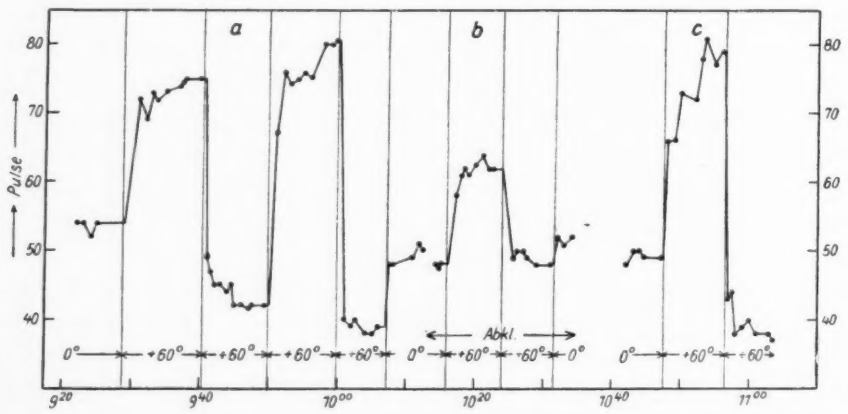

Fig. 3.—*a* and *c*, Pulse rate in horizontal (0°), head-up (+60°), and head-down positions (–60°); *b*, the corresponding values after cutting off the circulation to both lower extremities by pneumatic cuffs applied while the subject was in a horizontal position. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 190-203, 1939.)

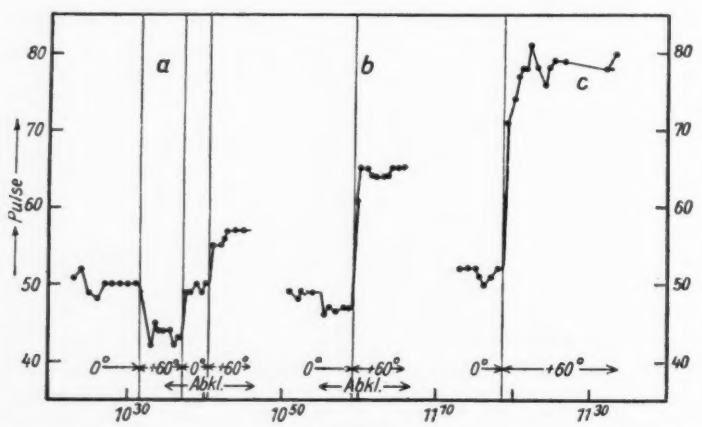

Fig. 4.—*a* and *b*, Pulse rate in different positions after cutting off the circulation to both lower extremities while the subject was: *a*, at –60°; *b*, at 0°; *c*, control determination without pressure. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 190-203, 1939.)

Fig. 4 shows the pulse rate in +60° (head-up): in Experiment a with "emptied" legs (the cuffs were inflated in –60° before tilting); in Experiment b with practically normal blood filling of the legs (the cuffs were inflated in horizontal position before tilting); and in Experiment c

with maximal filling of the legs (no cuffs were used). With empty legs (Experiment a) the pulse difference between horizontal and standing position (+60°) was 5 to 7 beats per minute; with normal filling (Experiment b), 15 to 16 per minute; and with maximal filling (Experiment c), 30 beats per minute. The subnormal pulse values in head-down position could be shown in the same way to be closely related to the amount of blood accumulated in the legs. With blood-filled legs (the cuffs were inflated in standing position before tilting to head-down posi-

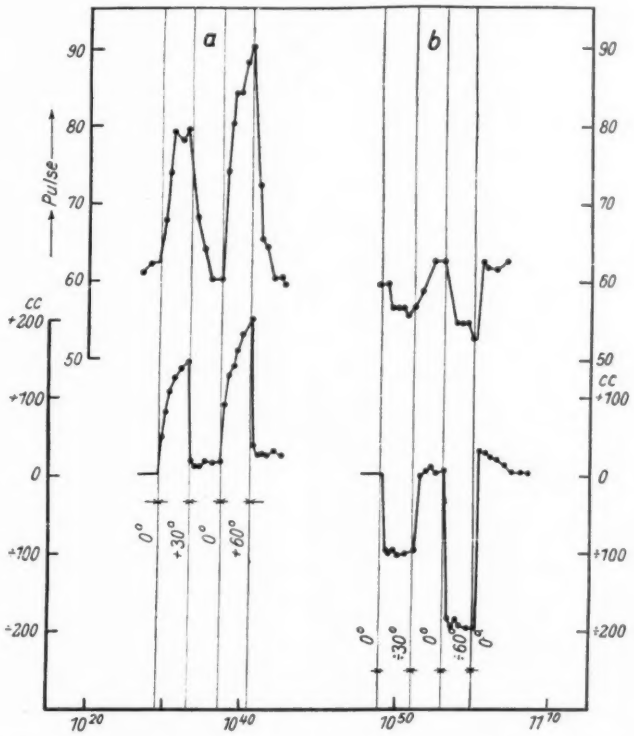

Fig. 5.—Pulse and plethysmogram (small plethysmograph); *a*, on changing positions from 0° to head-upward +30° and +60°; *b*, on changing positions from 0° to head-down position −30° and −60°. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 190-203, 1939.)

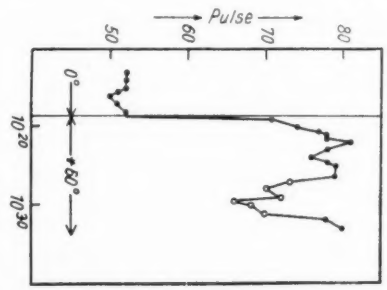

Fig. 6.—Pulse rate in the passive standing position (+60°). Black circles indicate pulse rate while standing quiet. Open circles indicate pulse rate on voluntary contraction of leg muscles. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 190-203, 1939.)

tion) the pulse rate would be 50 to 55 instead of 40 or even below 40 in cases where the circulation to the legs was free (compare with Fig. 3).

Fig. 5 shows pulse rate and plethysmogram (a smaller plethysmograph was used than the one mentioned before) from the same subject in positions between +60 and –60°. The relation between amount of blood in the legs and pulse rate is here very clear. The most surprising result may be the fact that the emptying of the legs is so different in –30 and –60°. We expected to find very nearly the same volume in the two positions, but, as Fig. 5 shows this is by no means true, apparently it is quite difficult to make the deeper veins collapse.

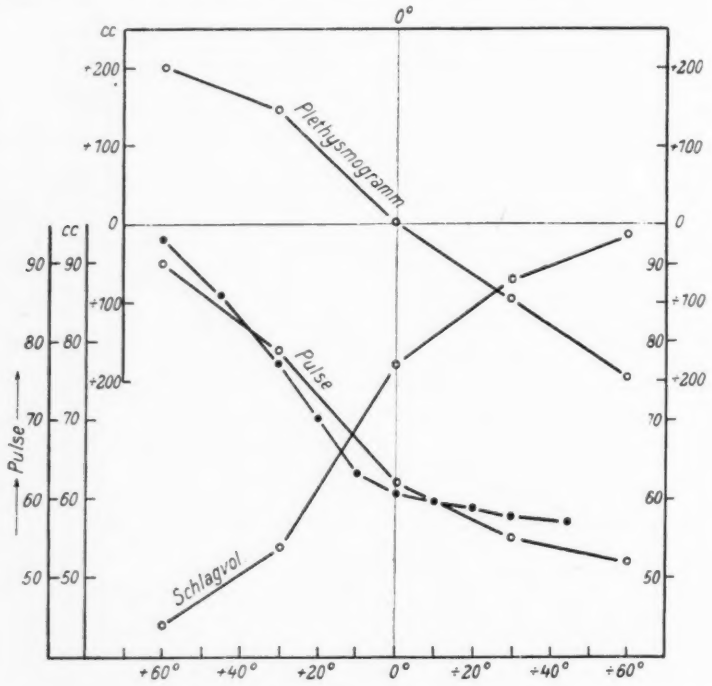

Fig. 7.—Plethysmogram, pulse rate, and output of the heart in various positions between the head-up (+60°) and the head-down (–60°) positions. The values indicated by open circles are derived from the same experiment. The values were determined about two to three minutes after change of position. (From Asmussen et al.: Skandinav. Arch f. Physiol. **81**: 190-203, 1939.)

Fig. 6 demonstrates the importance of muscular contractions for the circulation. The subject has been tilted to head-up position (+60°) and in a few minutes the pulse rate went up from 50 to 80. The subject now started to make static contractions of his leg muscles and the next countings showed a pulse of 65 to 70. As soon as the contractions stopped, the pulse rate went up to 80 again. The muscle contractions forced the blood out of the veins back to the central vessels.

In Fig. 7 measurements of leg volume, pulse rate, and stroke volume from the same experiment were plotted together. The stroke volume varied between 45 c.c. in +60° (head-up position) and almost 100 c.c. in –60° (head-down); even larger changes are shown in Table I.

TABLE I

O_2 CONSUMPTION AND CIRCULATION IN DIFFERENT POSTURES

POSTURE	ARTERIOVENOUS O_2 DIFFERENCE C.C./L.	O_2 CONSUMPTION C.C./MIN.	CARDIAC OUTPUT L./MIN.	PULSE RATE	STROKE VOLUME (C.C.)
+60°	57, 62	240, 245	4.05	79, 98, 91, 100	44
(head-up)	Avg. 60	Avg. 243		Avg. 92	
+45°	62, 61, 58	237, 242, 242	4.0	77, 80, 81	51
(head-up)	Avg. 60	Avg. 241		Avg. 79	
0°	51, 55, 54, 49, 50	249, 249, 257, 242	4.8	55, 57, 52, 54	87
(horizontal)	Avg. 52	Avg. 249		Avg. 55	
−60°	54, 49, 51	250, 252	4.9	45, 38, 41, 45	117
(head-down)	Avg. 51	Avg. 251		Avg. 42	

The close connection demonstrated between peripheral blood distribution and pulse rate gives a strong support for the opinion that the changes in pulse rate can be regarded as essential parts of a mechanism securing an adequate circulation rate. In head-down position we found that the pressure in the central veins (method of Henderson) was 10 to 15 cm. of blood higher when measured with empty legs than when measured with blood-filled legs. The higher venous pressure found in experiments with emptied legs must be due to an increased filling of the central veins. The blood that has been forced out of the lower extremities seems to have moved to the central vessels, increasing the pressure here and diminishing the air space in the thorax by about the same volume (Table II).

TABLE II

VITAL CAPACITY WITH "EMPTY" AND "FILLED" LEGS IN HEAD-DOWN POSITION (−60°)

SUBJECT	E. A.	E. H. C.	T. S.
Vital capacity with "filled" legs (L.)	4.83	5.04	4.67
	4.88	5.20	4.62
	4.81	5.10	4.63
	Avg. 4.84	Avg. 5.11	Avg. 4.64
Vital capacity with "empty" legs (L.)	4.35	4.60	4.23
	4.33	4.69	4.18
	4.35	4.61	4.28
	Avg. 4.34	Avg. 4.63	Avg. 4.23
Difference in vital capacity with "filled" and "empty" legs (L.)	0.50	0.48	0.41

The mere fact that the venous pressure is kept high and the air space of the lungs is kept low as long as the head-down position is maintained shows that the blood from the legs is not taken up by real blood depots.

If the pulse rate of the standing or horizontal position were maintained in head-down position, with increased venous pressure and consequently increased diastolic filling and increased stroke volume, the cardiac output and the arterial pressure would increase and would be kept at an unnecessarily high level. By decreasing the pulse rate, the cardiac output can be kept normal in spite of the increased venous pressure and increased stroke volume, provided only that the diastolic filling

does not increase in proportion to the longer diastolic period. From that point of view it is quite natural to look upon the lower pulse rate in head-down position as a compensation for the increased pressure in the central veins, and in the same way to take the fast pulse rate in the standing position as a compensatory arrangement against a decreased pressure in the central veins.

An increased pressure in the central veins, according to Bainbridge, should induce a faster pulse rate. The pulse acceleration found during muscular exercise is very often explained as being brought about in that way. As our results show, we have not been able to find any sign of a Bainbridge reflex and under these circumstances it would be very unfortunate if it really existed; in head-down position it would counteract the regulatory arrangements put into action to secure a normal cardiac output and a normal arterial blood pressure. The experimental proofs that a Bainbridge reflex is released by an increased pressure in the central veins are not very convincing.

The pulse curves show that the changes in heart rate take place immediately after tilting, which indicates that they must have the character of a reflex.

In the arteries close to the heart only small changes in pressure will take place by tilting the subject, while the pressure in the more peripheral arteries may change significantly according to the distance from the heart. Consequently small changes only will take place in the aorta and rather larger changes in the sinus caroticus; therefore one might expect that the high pulse rate in the standing position might be due to a decreased pressure in the sinus and the low pulse in head-down position be due to an increased pressure in the sinus. The pressure changes should be the direct effect of a lifting or lowering of the sinus in relation to the heart. The results of our experiments give a strong indication against that explanation. As shown by Fig. 3, practically the whole effect of tilting could be obtained simply by changing the amount of blood in the central vessels and here the relation between heart and sinus is unchanged. This fact also makes it very unlikely that the low pulse rate in head-down position should be due to an increased pressure in the fourth ventricle of the brain brought about by hydrostatic forces in that position.

The reason for the pulse changes cannot be a primary change of pressure in the arteries but must be correlated to the shifting of blood from or to the central veins. However, a difference in venous pressure, as already pointed out, can influence the arterial pressure via the cardiac output. If a decreased venous pressure brings about a lower cardiac output it also will give a lower arterial pressure; via the pressosensible mechanism the pulse rate will increase as much as possible to compensate the low filling pressure of the heart and secure an adequate cardiac output.

The results of the following experiments will show that a close dependence exists between arterial blood pressure and heart rate and can be demonstrated not only on operated animals but also on human beings with the regulation of circulation intact. Fig. 8 shows systolic blood pressure and pulse rate for three normal subjects in experiments where

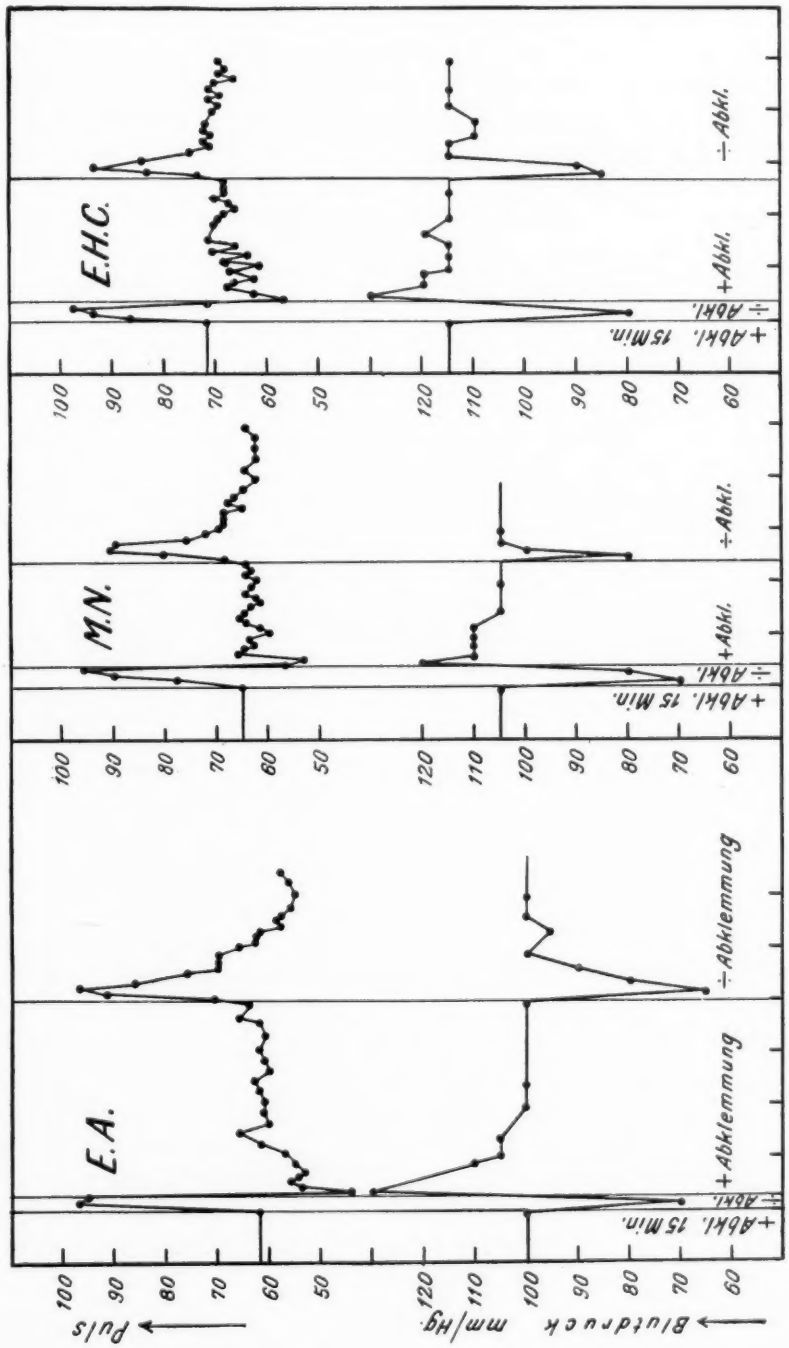

Fig. 8.—The blood pressure and pulse rate on repeated cutting off and opening of the circulation to both extremities. (From Asmussen et al.: Skandinav. Arch. f. Physiol. **79**: 32-38, 1938.)

marked changes in the functions mentioned were produced by a severe anoxemia in the leg muscles. The subjects were sitting in an easy chair and pneumatic cuffs round the thighs were inflated to a pressure of 300 mm. Hg for fifteen minutes. The pressure was then released for ten to twenty seconds and suddenly put on again and kept on for a few minutes before it was released finally. As Fig. 8 shows, the first release of pressure will induce a steep fall in blood pressure and simultaneously a marked increase in heart rate, and, when the circulation to the legs is blocked the second time, the blood pressure will suddenly rise above the normal value, while the pulse rate will reach subnormal values. In these experiments the pressure regulation has not been sufficient to compensate for the effect of a sudden and large demand for blood to the anoxemic area in the leg muscles and the arterial pressure drops down;

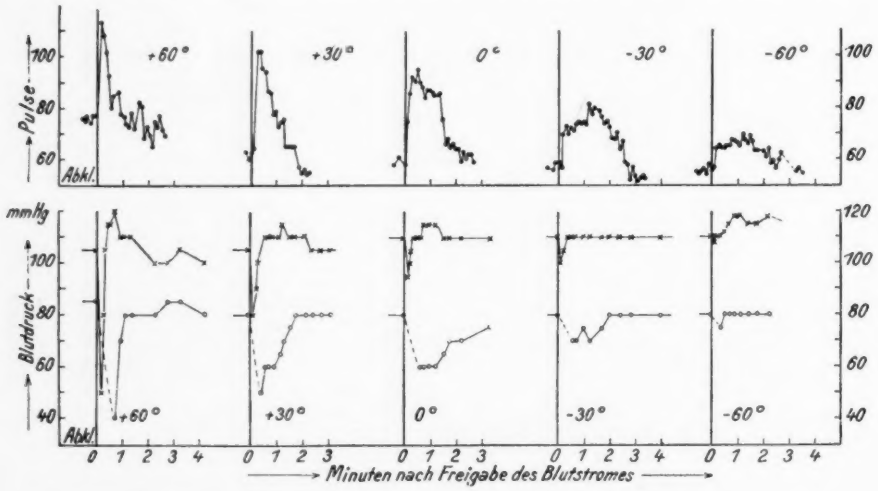

Fig. 9.—Pulse rate and blood pressure in reactive hyperemia in different positions of the body. (Release of pressure on the blood stream in both lower extremities after about fifteen minutes of pressure.) (From Asmussen et al.: Skandinav. Arch. f. Physiol. **81**: 204-213, 1939.)

the pressosensible reflexes are then released and as a part of the compensatory mechanisms the pulse rate is increased. If the fast blood stream to the anoxemic areas is suddenly stopped, the blood pressure goes up and consequently the pulse slows down below normal. In the following experiments this procedure was used to test the effectiveness of blood pressure regulation in different postures.

Fig. 9 shows the result of such experiments. The subject was placed on the tilting board and after a sufficient period of rest (one hour) the cuffs round the thighs were inflated and the subject was tilted to the desired posture. The pressure was then released fifteen minutes later and arterial blood pressure and pulse rate were registered during the next minutes. Fig. 9 shows that the pressure control is almost perfect in –60° (head-down position) and very severely affected in +60° (head-up), but in all cases the normal pressure was established again very soon.

In the experiment shown in Fig. 10 the period of anoxemia lasted twenty minutes, and, when the pressure was released in +60°, the subject showed the normal drop in blood pressure and increased heart rate; a normal pressure value was reached in about one minute, after which, however, a second drop in pressure took place, the subject almost fainted and had to be tilted back to horizontal and even to head-down position before the pressure again reached normal values. It is very interesting and perhaps a fact of great significance that the second drop in pressure was not, as usual, followed by an increased heart rate.

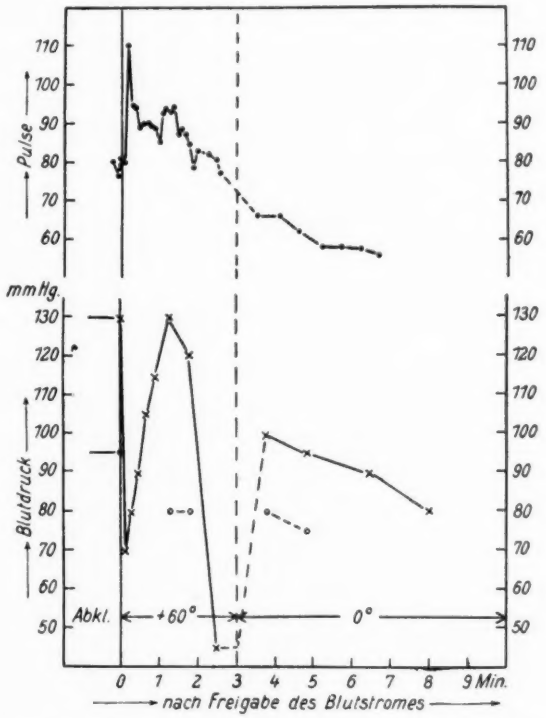

Fig. 10.—Pulse rate and blood pressure after release of pressure on the blood stream with subject in the upright position (+60°). (Pressure on both lower extremities for twenty minutes.) (From Asmussen et al.: Skandinav. Arch. f. Physiol. 81: 204-213, 1939.)

The plethysmographic records showed that the filling up of blood in the lower extremities was of the same magnitude in cases where the effect of tilting was combined with anoxemia in the leg muscles. In the latter case the filling up took place much faster; in ten to twenty seconds the same swelling of the legs had taken place that would take five minutes in the case of tilting only.

CONCLUSIONS

Our experiments indicate that the circulation rate in quiet standing is on the lower limit of what is really desirable and that, even if the fast pulse rate in the standing position in itself is no sign of insufficiency, it

indicates on the other hand that some extra stress is put onto the pressure-regulating mechanism.

A diminished cardiac output during quiet standing has to be looked upon as a sign of insufficiency, even if the O_2 consumption and the arterial blood pressure remain normal. The vessels of the lower extremities are distended by hydrostatic forces; a large amount of blood remains there and consequently the filling and pressure of the central veins get too low to secure an adequate filling of the heart and a normal cardiac output. Through an increased heart rate and through compensatory contractions of the vessels in certain organs (e.g., in the intestines) a normal arterial blood pressure might be obtained. However, it must be remembered that a diminished circulation rate to these organs with partly contracted vessels locally may have an unfavorable effect. It may be of great importance that circulatory insufficiency due to a peripheral dilation of the vessels or to a loss of blood can be counteracted by an elevation of the lower extremities. The autotransfusion of blood that can be made in this way may be of great significance. In cases where a circulatory insufficiency due to a disproportion between the total blood volume and the capacity of the vessels is obvious, any posture where hydrostatic forces can induce an increased filling of the vessels of the lower extremities should be avoided. Even a small decrease in cardiac output may mean a rather severe insufficiency of the circulation of certain organs. The beneficial effect of the reclining position to a great extent may be due to the abundant blood supply to the different organs obtainable in that position.*

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TUMOR EMBOLISM OF THE COMMON FEMORAL ARTERY, TREATED BY EMBOLECTOMY AND HEPARIN*

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ACCORDING to all experience, occluding embolisms of the arteries of the circulatory system resemble each other in two respects especially: (1) with reference to the source, which apart from rare cases of so-called paradoxical embolism is generally the left half of the heart and occasionally the central parts of the aorta; and (2) with reference to the material in the embolus itself, which usually consists of centrally formed thrombus matter.†

The case related below differed in both these respects: (1) the source of the embolus was undoubtedly the lungs; and (2) the material in the embolus mainly consisted of tissue of a malignant tumor. In addition to its interest from an etiological point of view, the case also was interesting therapeutically, as certain possibilities had to be considered with reference to the treatment, which will be discussed below; and as heparinization during and after the operation proved to be of great value, a question that is of great current interest. In the clinical description of the case I shall discuss the operation and the subsequent course in detail in order to demonstrate as adequately as possible the remarkably favorable effect of the heparinization.

CASE REPORT.—Mrs. S. K., born on Aug. 13, 1903 (Diary No. 796/39). The earlier history, the main features of which will be seen in Fig. 1, is of interest in this case. The patient enjoyed good health and attended to her household work until the beginning of 1939, when symptoms from the lungs appeared. On Feb. 11 an x-ray of the lungs disclosed several morbid spots in the parenchyma (Fig. 2). These spots were interpreted as metastases of the sarcoma in the right tibia (Prof. Hugo Laurell), for which the right leg had been amputated in 1937. She then remained at home, confined to her bed, until Feb. 27, when symptoms of embolism in the left leg made their appearance in connection with an attack of coughing.

The embolism started insidiously at about 1:00 P.M. when the patient experienced slight pains in the lumbar region and, after a while, a heavy feeling in the left leg. By degrees, sensations of cold and numbness set in and, after a few hours, a moderate aching pain. This pain increased toward the evening, a physician therefore being called in. His diagnosis was embolism; he gave morphine and referred the patient to the hospital.

On Feb. 27, 1939, at 9:00 P.M. the general condition was but little affected. In good flesh. There was distinct cyanosis of the lips and slight dyspnea when speaking. The temperature was 37.2° C., pulse, 100/min., regular, well filled, heart action, unimpaired.

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Received for publication, January 5, 1940.

†In this connection the cases in which a foreign body has entered the circulatory system from without and started wandering are not taken into consideration.

In the left leg and foot there were moderate, aching pains, with sensations of cold and numbness in the limb. The picture presented was typical of occluding embolism of arteria femoralis communis, the circulation in the leg being stopped. The oscillometer recorded nothing at the middle of the thigh, but the pulse could be palpated up at the groin.

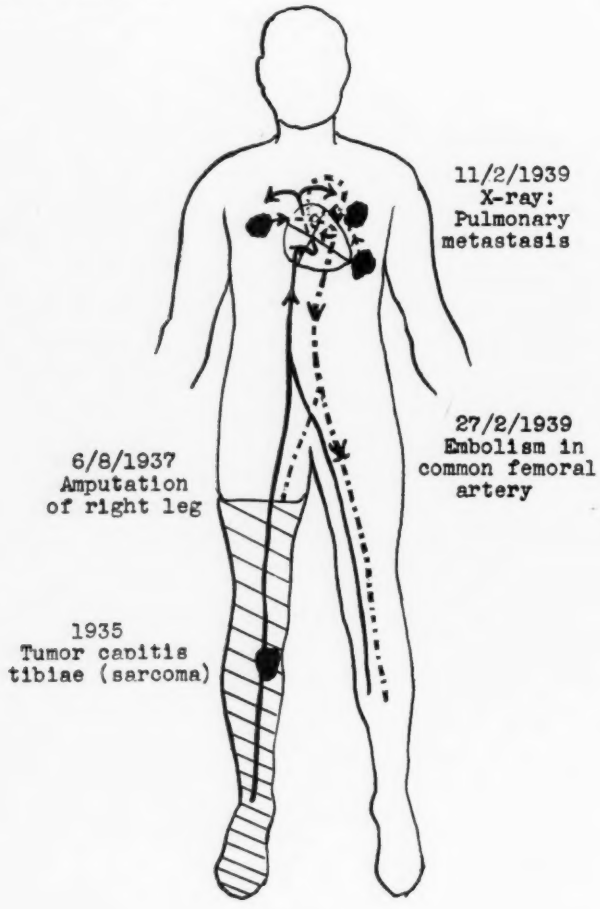

Fig. 1.

The diagnosis of embolism of the left common femoral artery was considered quite definite. It was also thought certain that whatever steps were taken could only be of a palliative character, since the patient's lung metastases would probably cause death in a fairly short time. The disturbance of the circulation in the leg was so severe that it undoubtedly would lead to gangrene, possibly amputation. Considering the fact that the patient both clinically and roentgenologically lacked all signs of heart diseases and that large sarcoma metastases had been demonstrated in the lungs, there was furthermore the possibility of tumor embolism developing, with the consequent results of such embolism. Under these conditions it could not be considered correct to start a vasodilator treatment, for instance with eupaverin,

especially since the effect of such a treatment is very doubtful when the embolus is situated as in this case. Considering the patient's youth and, in spite of the present ailment, her fairly good general condition, it was thought well justified to suggest embolectomy with a view to sparing her the suffering associated with gangrene and the possible development of a tumor in the remaining leg. Furthermore, it was impossible, of course, to know how long she might live with her lung metastases.

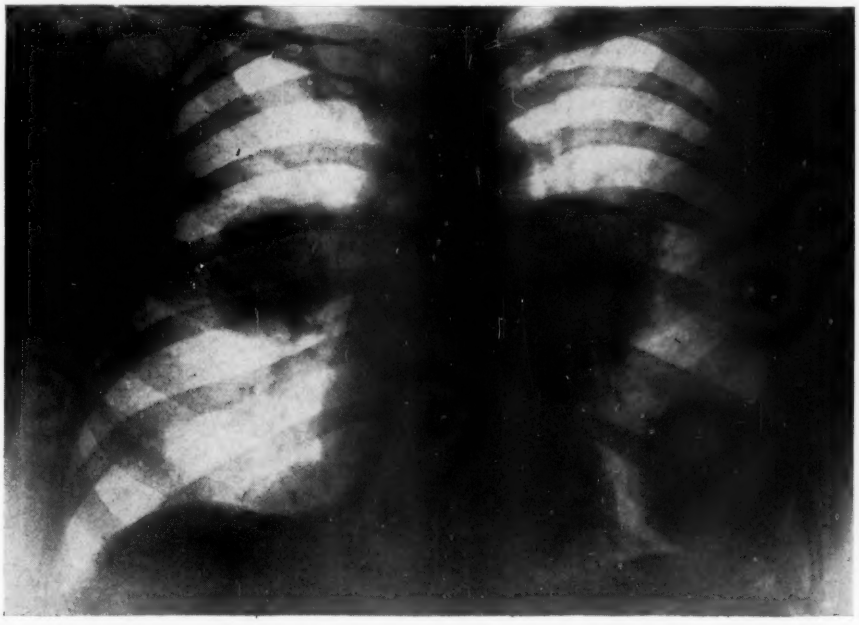

Fig. 2.—X-ray, taken Nov. 2, 1939, showing pulmonary metastases.

Embolectomy of the left common femoral artery with removal of secondary post-embolic thrombus, and intra-arterial injection of heparin were performed at 11:30 P.M. (about ten hours after the symptoms appearing). Local anesthesia with novocain and adrenaline was used.

The femoral artery was exposed from Poupart's ligament some distance down the thigh. It was of normal width and pulsated strongly about 2 cm. below the ligament. Farther down it was of the same width but felt filled with solid matter down to the spot where the deep femoral artery branched off. Toward its distal end the artery was distinctly thinner (about the width of a pencil). It was not collapsed but was bluish, and felt firm when palpated; evidently it was filled with a secondary postembolic thrombus. After the ordinary preparations, an incision was made above the lower pole of the embolus, the upper part of the secondary thrombus simultaneously being exposed. The stream of blood was not strong enough to press out the embolus, and the upper part of the vessel, therefore, was drawn tight. The thrombus was seized carefully with a forceps, and, when cautiously removed in the central direction, a piece, about 7 cm. long, was brought out. The embolus itself was then easily massaged out, the peripheral end of the artery being closed. There appeared meaty, grayish red masses, which did not resemble a thrombus. A spurting stream of blood followed, which was allowed

to rinse the wound. When the artery had been closed on either side of the incision, with the aid of soft rubber tubes, there occurred strong collateral bleeding from arteria profunda which was closed with a third tube. After controlling the stream of blood, the artery was sutured. The blood pulsated past the arteriotomy and the circulation in the leg and foot improved, the toes remaining white, however. After a while the pulsation in the artery ceased and it again felt filled. The suture was undone, and, upon massaging the artery, clots and fragments of the embolus appeared, similar to those already removed, a stream of blood then spurting out. The suture, which had to be reinforced to make it tight, was renewed. This time there were again but temporary pulsations in the artery, but the passage was opened down to the deep femoral artery and the upper tube therefore moved below that artery. It was decided that a renewed try should be made a little farther down and that, when the obstacle in the artery had been removed, eupaverin should be injected. This had been done by Denk experimentally in dogs and in one or two cases (according to his last publication, 1938) in man without any detrimental secondary effects being observed. When some red thrombi had been removed

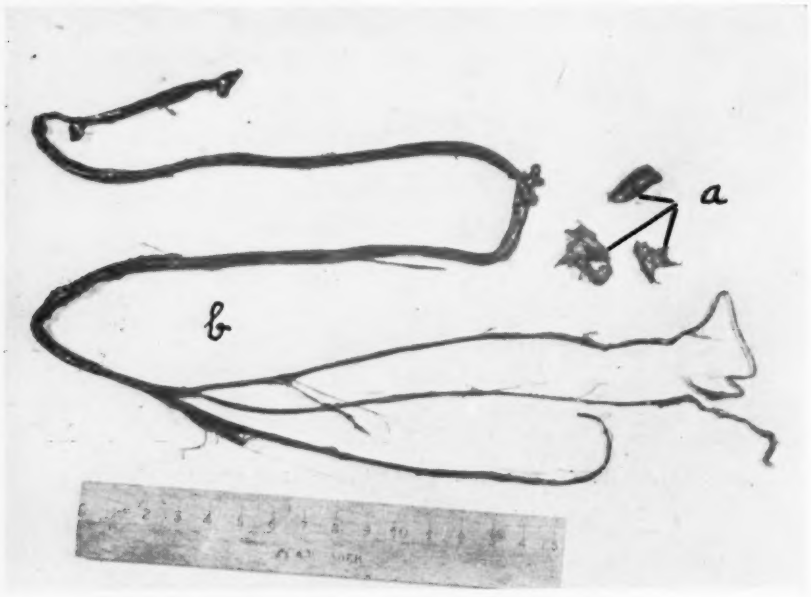

Fig. 3.—Emboli of tumor tissue (*a*) and postembolic thrombus (*b*).

by an incision farther down and a spurting stream of blood had appeared and the suture made, two ampoules of eupaverin (0.06 Gm.) were slowly injected into the artery. The patient stated almost immediately that she felt an acute, smarting pain down the leg. The pulsation passed the last suture and the color of the foot improved slightly, though for a short while only, the pulsations below the sutures also ceasing rather rapidly. It was presumed that there was an occluding thrombus farther down and that it was added to on the proximal side after each cleansing. Upon palpating the distal part of the artery, the impression was created that it was filled with a solid mass. Another incision was thus made farther down; there was no bleeding; after massaging out fresh clots from the central part, a spurting stream of blood appeared, but there was still no bleeding from the peripheral part. A paraffined probe was introduced a short distance into the peripheral part; it encountered no resistance, but when it was pulled out the upper end of a black-red thrombus appeared and was seized with a forceps and about 75 cm. pulled

out (Fig. 3). It felt rather firm and had apparently been in the artery the whole time. It was followed by fairly heavy bleeding. After renewed massage on the central side, the peripheral tube being stopped, new fresh clots appeared followed by a spurting stream of blood. A suture was made, whereupon 1 ampoule of eupaverin (0.03 Gm.) was injected into the artery, also this time followed by an acute, smarting pain down the leg. The foot and toes immediately improved in color and the circulation appeared to have started afresh. Pulsations were felt, too, as far in the peripheral direction as could be ascertained with the finger. While awaiting developments, the artery was dabbed with sodium citrate, but after about ten minutes the circulation was evidently impaired; the foot gradually became entirely white, the pulsations ceased, and around the sutures the artery was felt to be filled with soft clots. It was thus evident that no satisfactory result could be anticipated, because of the decided tendency to thrombosis; postembolic thrombosis had occurred throughout practically the whole limb, and repeated arteriotomies within a short while had been followed by clotting around the sutures, injections of eupaverin into the artery not being sufficient to prevent this clotting. Under these conditions it was considered of no avail to make additional tries to restore the circulation in the artery unless the blood's tendency to coagulate could be mastered. It was thought that heparin offered a solution worth testing, and, since after four arteriotomies lasting well over one hour the patient's general condition was practically unchanged and good, it was decided that another endeavor should be made. It was presumed that the chances of a satisfactory result would be best if the passage in the artery was first restored and heparin immediately injected into the artery on the central side of the sutures. The middle suture was severed; clots were massaged out from both sides, followed from above by a spurting stream and from below by a profuse stream of blood; the opening then was sutured and made completely tight. A short distance above the upper suture there was immediately injected, very slowly, 2 c.c. of a 5 per cent solution of heparin (100 mg.*). While the injection was being performed, a little blood could be seen starting to ooze out between the sutures in the artery and even in the holes from the eupaverin injections, which previously had been quite dry. A little while after this injection, 1 ampoule of eupaverin was also given. The oozing bleeding gradually ceased. The pulse continued, the foot had a good color and felt rather warm, and the patient could move her toes. The operation was concluded.

Subsequent Course.—After the operation the oscillometer gave small registrations across the calf. The leg and foot were subjectively and objectively warm. The patient had no pains. The general condition was satisfactory. She was given cautious heat treatment along the limb; eupaverin was administered intravenously during the night, 1 ampoule every other hour, and during the following days three times daily; herparin was given intravenously three times daily, 1 c.c. (50 mg.) for 3 days.

The circulation in the limb remained. The day after the operation there were no subjective troubles; the foot felt warm, and sensibility and motility were satisfactory; the strength of the ankle joint was diminished, however, especially when bent backward. The muscles of the calf were firm, indicating an ischemic injury as a result of the ar-

*Milligram of standard heparin according to Jorpes, corresponding to 500 and 100 cat units respectively, according to the earlier and later designations used by Murray and Best.

terial stoppage which lasted for more than ten hours. Fig. 4 shows the skin temperature on the plantar surface (measured according to Ipsen) during the first days following the operation. The oscillometric

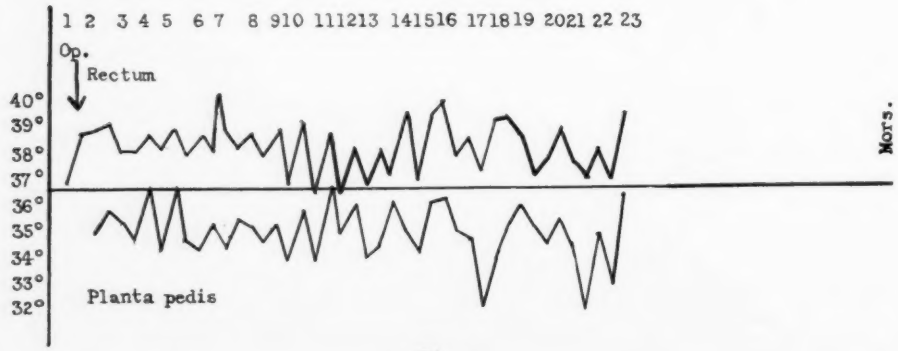

Fig. 4.

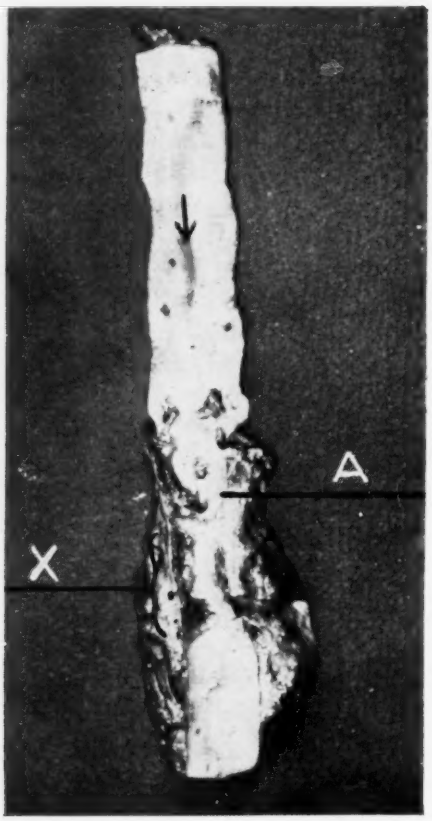

Fig. 5.—One of the incisions in the femoral artery with small thrombotic deposits on the intima (*X*); mouth of the deep femoral artery, *A*.

index for the calf was determined repeatedly and found to be 1.5. The wound healed per primam and the heparin treatment caused no secondary hemorrhage or other disturbance of the healing.

During the next few weeks the condition was fairly satisfactory, in spite of a fever and coughing, which was sometimes aggravated to bad attacks with dyspnea and cyanosis. On a few such occasions the patient brought up rather large solid lumps of tumor tissue, indicating a decidedly destructive growth on the part of the lung tumors, but there appeared no symptoms of new emboli. The condition of the limb remained unchanged and good, the motility even improved a little as a result of medicomechanic treatment. Finally the condition grew worse fairly rapidly in a few days and the patient died on March 31, one month after the embolism.

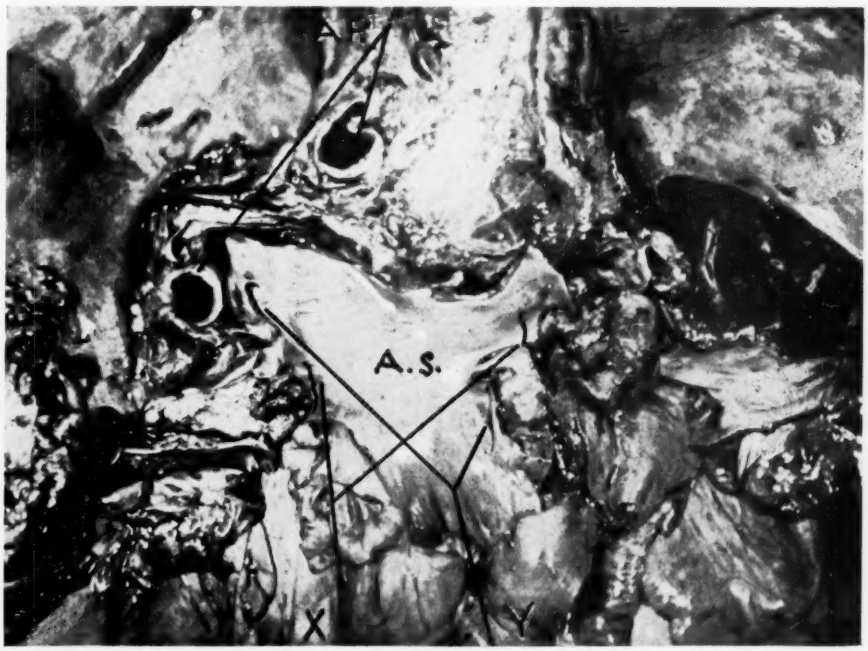

Fig. 6.—Heart and lungs from behind. Pulmonary veins occluded by tumor tissue (*X*); open pulmonary veins, *Y*; arteria pulmonalis, *A.P.*; atrium sinistrum, *A.S.*

The post mortem* in the main confirmed the clinical findings and I shall discuss only the findings in the femoral artery, lungs, and heart. Fig. 5 shows the femoral artery opened. The passage is free, but at the sutures the caliber is slightly constricted and in those places there are also some minor thrombotic deposits on the intima. The artery is surrounded by a rather thick periadventitial cicatricial tissue, a matter that has of late attracted a certain amount of attention (Fiolle, Haimovici, and others), and which has been indicated to be the cause of circulatory disturbances after successful embolectomies. In this case it apparently had no detrimental effect. The femoral circumflex arteries were filled with masses of thrombi.

*Post mortem performed by the Pathological Institute of the University of Uppsala.

Fig. 6 shows the lungs and heart from behind. The left auricle and the pulmonary veins are cut up and the pulmonary artery cut off where it branches. On either side the pulmonary veins are occluded by tumor tissue protruding from their mouths in the shape of rounded plugs. One branch is free on either side. On one side a tumor had broken into a main bronchus and on the other out into the pleura. The ventricles contained no thrombi, and, apart from its being slack, the heart displayed no anatomical changes.

Histologic Examination.—The histologic examination proved that the embolus consisted of tumor tissue together with thrombus matter, which was a possibility anticipated clinically. Fig. 7*A* shows a section through the embolus; the tissue consists of a giant-celled sarcoma, the structure of which fairly well resembles the primary tumor as it appears in an old section from a trial excision in 1937 (Fig. 7*B*); the figure also shows a piece of a tumor that was coughed up (*C*).

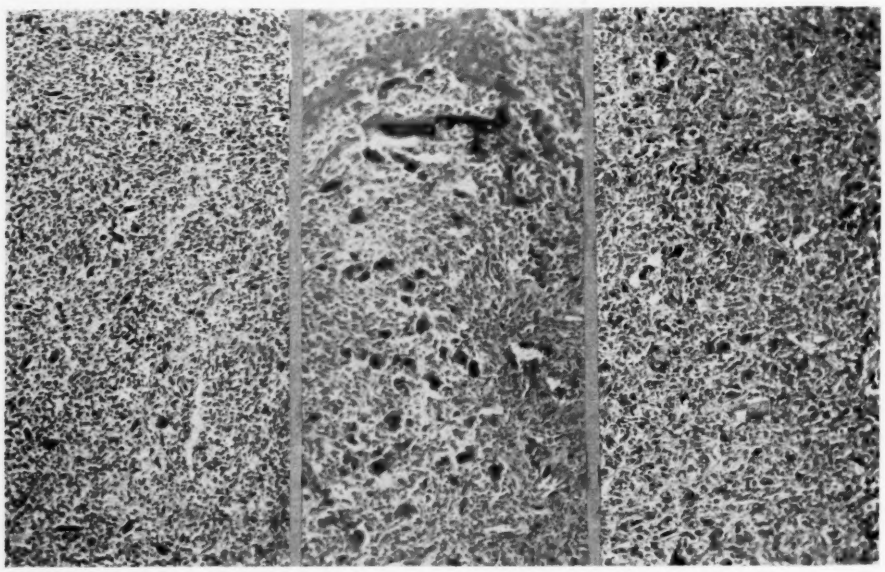

Fig. 7.—Sections from the embolus (*A*), the primary tumor in the right tibia (*B*), and a piece that was coughed up (*C*).

DISCUSSION

Source of Embolisms of the Arteries of the Circulatory System.—It was mentioned in the introduction that the commonest source of embolism of the arteries of the circulatory system is the left half of the heart (Bull, Key, Petitpierre, Groth, and others), where thrombi are formed, especially in various kinds of heart diseases, and are then thrown out. Sometimes the formation of thrombi on atheromatous wounds in central parts of the arterial system have caused embolism in more peripheral parts.

In rare cases thrombosis in the venous system or in the right auricle may have caused embolism of the arteries of the circulatory system, so-called paradoxical embolism. The first condition under which this occurs is, of course, a communication between the two halves of the heart, a foramen ovale apertum, or a defect in the septum ventriculorum (Louis). A persistant ductus arteriosus botalli is also a theoretical possibility, but this anomaly is so rare that it may be practically excluded. In spite of the fact that foramen ovale apertum in postmortem material is so common as to be found in 30 to 35 per cent of all cases (Hirschboeck, Koritschoner), transporation of thrombi from the right to the left auricle is probably quite rare; for, as a rule, foramen ovale has the character of a canal running obliquely through the septum atriorum, preventing a passage that way as its walls are pressed together by the pressure in the auricles. Experimentally, Gross demonstrated that emboli may pass through if the pressure in the right auricle is greater than in the left, but not when the pressure conditions are the other way round, this depending on the above-mentioned valve mechanism. A difference in pressure between the auricles favorable to paradoxical embolism arises as a result of pulmonary embolism (Haggart, Walker, Parkinson), and this facilitates a fairly reliable diag wosis of paradoxical limb embolism (Hirschboeck). In 1881 Zahn described the first case in which a thrombus was found just in the foramen ovale, and subsequently several such cases have been published; lately, for example, by Hirschboeck, Taylor, and Koritschoner, the last having collected twelve cases. In 1929 Key mentioned some cases treated by embolectomy in which the embolus was presumed to be of a paradoxical type; but, upon a closer study of them, it was found that in most of the cases objections could be raised against the presumption. On the basis of Bull's examinations, Key takes up a deprecatory attitude toward the possibility of paradoxical embolism, but he does not dispute the possibility of its having occurred. Nyström has published one case of embolectomy, among others, which from all appearances was paradoxical embolism. It would seem as if the above-mentioned cases in which a thrombus has been discovered in the foramen ovale are strong supports for the occurrence of paradoxical embolism. The objection has been raised that the thrombi may have been formed in the foramen ovale, but the findings published, e.g., by Koritschoner, and illustrated with photographs, seem to furnish convincing proof that we are concerned with the passage of an embolus.

The pulmonary veins may possibly be another source of embolism in the circulatory system, which has also been considered (Key, Lund). However, I have found no mention in the literature of any case of diagnosed occluding embolism in the circulatory system in which that

source was established. The case described above is thus of interest as the embolism undoubtedly emanated from the lungs.

Type of Embolus.—There is probably no doubt but that emboli removed by operation as a rule consist of thrombus matter, and it is presumably for that reason that they are generally not subjected to a microscopic examination. The histologic examination of the embolus described above, disclosed it to consist of sarcomatous tissue, on which thrombus matter had been deposited. It is in itself not uncommon that small fragments of malignant tumors get into the blood vessels and are transported with the blood, but it is probably a rare occurrence that large pieces, as in this case, are removed and cause a stoppage in one of the large arteries of the circulatory system. As far as I have been able to ascertain, the literature contains no record of such a case having been subjected to embolectomy. The case thus shows that it is necessary to count on the possibility of embolic tumors, since this possibility should be of great importance when choosing the method of treatment.

The wandering of the sarcoma in this case is interesting. It would appear to be certain that the pulmonary tumors were metastases. They were multiple and displayed good histologic agreement with the primary tumor. It is considered typical for sarcomas that they spread by way of the blood vessels. The primary tumor in this case was localized to caput tibiae and symptoms began to appear in 1935. Having spread via the venous system, lung metastases made their appearance, in the beginning of 1939, the disease then spreading to the left leg by way of the arterial system. The decidedly destructive growth of the pulmonary tumors and a certain brittleness of the tumor tissue undoubtedly have greatly facilitated the last-mentioned spreading; i.e., the embolism. Thus, tumors grew widely into bronchi and into the main branches of the pulmonary veins. The direct cause of fragments of intruding tumors, both in the bronchi and in the veins, being released and partly coughed up, partly flung out into the arterial system as emboli, was undoubtedly a coughing attack; for then, as is well known, the lungs are rapidly and strongly compressed and the pressure increases in bronchi as well as veins and endeavors to empty them. A plug of a tumor penetrating into the lumen is then easily broken off and flung out.

Treatment.—Embolisms in the upper limbs are generally better suited for conservative treatment with vasodilator agents, such as eupaverin, according to Denk, mainly because the collaterals are better preformed and thus there are better possibilities for an arterial supply of blood in the limb via other vessels than the one occluded. Conditions are far more unfavorable with reference to the lower limbs and the result of a conservative treatment is very doubtful, this having been demonstrated by a number of cases (Åkesson, Wiberg, Groth, and

others). I have discussed this question in another connection and refer to the paper in question.

A well-founded suspicion of a case being one of tumor embolism is of importance when determining whether the treatment is to be conservative or operative and considerably increases the misgivings about conservative therapy, especially in the case of embolism in the lower limbs. A piece of tumor that had been flung out would then be allowed to remain in the artery, possibly causing the development of a tumor in the limb.

Another matter worthy of special attention in this connection is the circulation in the limb in conjunction with embolism. There are reasons to presume that the extensive postembolic thrombosis starts as a coagulation of a blood column on the distal side of the embolus. If the embolus entirely occludes the artery and if, in addition, the collaterals are but little developed, the stoppage immediately causes a heavy drop in pressure on the distal side of the embolus, which results not only in a decrease in the caliber of the vessel, but also in the blood in the vessel being retarded, possibly stopped. (A spasm occurring, it may have a similar effect.) Due to the collaterals being different, this condition, which favors coagulation, is undoubtedly more decided in the lower limbs than in the upper. Other factors also influence the coagulation, special attention having been paid to the tendency of the blood itself, the coagulation differing from case to case. Lesions of the intima favor coagulation as the blood comes into direct contact with a tissue lacking endothelium. Similarly, it would appear probable that foreign tissues in the blood vessels, in this case tumor tissue, should favor coagulation.

There is good reason for assuming that subsequent to coagulation there is no flow of blood in the artery, even though the clot may not be of the normal caliber of the vessel. Owing to the drop in pressure in the artery after the stoppage, its wall will most probably be pressed against the clot. Merely as a result of the stoppage in the artery, causing the blood on the distal side of the embolus to be at a standstill or to move but slightly, but especially if postembolic thrombosis has started by the coagulation of that blood, the prospects of obtaining any kind of effect on the arteries by intravenous injections of eupaverin are thus nonexistent or in any case very small. The mouths of the collaterals are stopped and furthermore there is but little possibility for the eupaverin to advance in the arterial system of the obstructed limb. Eupaverin is an agent producing a direct effect on the smooth muscles in the vascular wall and has no remote effect conveyed by the nerves. Nor has intravenous treatment with eupaverin been established in any way to prevent secondary thrombosis (Åkesson) and the same appears to be true with reference to local intra-arterial injections, for in the case now described coagulation started

afresh after such injections. Östling recently recorded a favorable effect of eupaverin injected into the artery after embolectomy and explains this by a condition of spasms immediately having been terminated. There appears to have been no postembolic thrombosis in his case.

Several reasons thus indicate that in cases of recently occluding large embolisms in the lower limbs vasodilator treatment should not be attempted, especially if there are reasons for suspecting tumor embolism. Operative treatment should be resorted to instead, first of all embolectomy. In the above described case it proved, however, that, in spite of the embolus' being removed together with a postembolic thrombus covering practically the whole length of the limb and although intra-arterial injections of eupaverin were administered, the circulation did not start, due to a decided tendency to coagulation. A favorable result would certainly not have been attained unless an anticoagulant, heparin, had been available.

Heparin Treatment.—Heparin is a physiologic anticoagulant which is nontoxic in its present pure form. There is already a fairly extensive literature on its properties and its clinical and experimental use to date. In the April, 1939, issue of this JOURNAL Mason published a summary and recently Jorpes published a monograph on the subject (which appeared in Swedish as well as in English).

As regards our results after embolectomy when the embolus was difficult to reach (aorta aa. iliacae), I have previously published a paper in which I discussed the well-known fact that secondary thrombosis has an extremely unfavorable effect on the prognosis and hinted at the possibility of reducing it by the use of heparin. At that time there had been published no clinical experiences of heparinization in conjunction with vasosurgical operations. Pure heparin having become available, the experiences have been very favorable, especially in cases of postoperative thromboprophylaxis (Murray and Best, in Toronto; Crafoord, in Stockholm), as have been the experiences of vascular operations in animals. In this connection Murray and Best's experiments (1938) are of major interest. Upon performing experimental embolectomy in dogs twenty-four to seventy-two hours after sterile foreign bodies and pieces of thrombi had been placed in arterial bifurcations, postoperative thrombosis and negative results were recorded in all the nonheparinizated cases; whereas, general or regional heparinization resulted in the circulation being restored after every embolectomy. In order to ascertain the risks of secondary hemorrhages, Olovson (1938-1939) performed arteriotomies, also in dogs, that were strongly heparinizated, and was in all the cases able to arrest the bleeding without any great difficulties when the suture had been made.

The clinical experience of heparinization in these operations is as yet very limited. A study of the recent literature, occasioned by the case described above, disclosed that heparin has been used in a few cases of embolectomy in Toronto and at Örebro in Sweden. Murray and Best in 1938 gave a brief report on five cases, all of which passed off favorably. One of these cases was stated to be unfavorable from the outset and was not operated upon until after twenty-five hours. Judging from the information submitted, secondary thrombosis did not occur. The hemostasis caused no trouble. At the surgical congress in Berlin in 1939, Lindgren reported on three arterial operations in which heparin had been used. Two of his cases were embolectomies and the results were good. Secondary thrombosis does not seem to have occurred. In one of the cases the hemostasis caused trouble. In the case reported by me, the tendency to renewed thrombosis was very pronounced and thrombi were reformed after no less than four cleansings. Nevertheless, the effect was good after the fifth endeavor when heparin was used and there was no renewed coagulation, the circulation being restored. In this case the hemostasis caused no difficulties. This case, perhaps more than those mentioned above, promises increased possibilities of mastering the secondary thrombosis and improving the prognosis after embolectomy.

A few words may be added regarding the administration and dosing of the heparin and regarding the hemostasis. Incidentally, I must state that heparin retards the formation of thrombin but has no effect if coagulation has already occurred. This is its favorable effect which should be utilized. The dangers caused by the use of heparin in arterial operations are postoperative bleeding and greater difficulties in achieving hemostasis. This is the unfavorable effect of the agent, to be avoided or reduced. By administering the heparin at the right moment and in suitable doses, a successful result should be obtained with reference to these two respects.

As regards the right moment for heparinization, it is, of course, necessary to determine it according to the conditions in each special case. Olovson claimed that heparin fills its most important mission before the operation, when it is to prevent postembolic thrombosis, and he suggests preoperative injections of 100 to 150 mg. every other hour, to be started as soon as possible. In the operation described above, it appeared quite clear to me (postembolic thrombosis already existing) that the best effect of heparin ought to be obtained if the artery was first cleaned and closed, a regional injection then being made into the artery. Murray and Best as well as Lindgren adopted the same procedure. It would appear as if Olovson, when making his proposal, did not pay sufficient attention to the disadvantage of performing the operation after heparin had been administered. This is

illustrated by one of Lindgren's cases. It was an aortic embolism with simultaneous embolisms in the two external iliac arteries, and arteriotomies were performed in three places, first in the aorta and then in the two femoral arteries. When the aortotomy had been sutured, a total of 90 mg. of heparin was injected in two doses with an interval of twenty minutes between injections. The aortotomy was then tight and remained so, but the process of arresting the hemorrhage after the sutures of the arteriotomies in the femoral arteries, which were performed after heparinization, was found to be very troublesome and revision was subsequently necessary due to bleeding. This would appear to be the only case of embolectomy in man hitherto made after heparinization.

It is certainly too early to draw any definite conclusions as to the best procedure, on the basis of the few cases so far published, but the experience gained, though it may, of course, partly be the result of accidents, would appear to supply certain hints as regards the administration that are worthy of attention. It is, of course, of extreme importance, from the very beginning, that this excellent and serviceable anticoagulant is not brought into disrepute owing to complications that possibly may be avoided. Doing a preoperative heparinization, however, we must take risks of considerable disadvantages (difficulty in hemostasis, afterbleeding). With this fact in mind, we ought to consider the obtainable advantages of this administration. In those late cases with a large postembolic thrombosis running out in the branches of the artery already occurred (Fig. 3), a preoperative heparinization is of no use, because the heparin cannot work in the blocked artery. It has been demonstrated that in a number of cases even a postembolic thrombus of considerable length has been pulled out and in my case that re-coagulation through postoperative heparinization may be avoided.

In early cases without or with only a slight postembolic thrombosis heparin may work favorably through collaterals, but, on the other hand, one or two hours' delay, before taking the patient to a hospital, seems to involve less risk than heparinization before the transport. Furthermore, it is not very likely that the general practitioner originally in charge of the case will have heparin available, and procuring it will mean a loss of valuable time. If the patient is in hospital and it has been decided that the operation shall be performed, the heparinization should be put off until the artery is free and the arteriotomy closed. This procedure would seem to me to be the least dangerous manner in which to utilize the favorable effect of heparin.

General rules for the dosing, based on sufficient clinical experiences, are as yet lacking. It goes without saying that the smallest effective dose must be the aim. In our case, 100 mg. injected intra-arterially

proved to be quite effective and entailed no complications. This dose corresponds to a little more than 1 mg. per kilogram of body weight. (The patient was a heavy person with considerable adipositas.) Lindgren recommends a more cautious dosing, 2/3 mg. per kilogram of body weight. In one of his cases this dose produced a coagulation time of ten minutes, which remained after four hours and which he considers sufficient. The dosing during the subsequent course should, according to Lindgren, be determined from case to case, on the basis of repeated determinations of the coagulation time. Referring to their experimental examinations, Murray and Best consider that the risk for thrombosis ceases seventy-two hours after the operation. In my case it was found that a supply of 150 mg. per twenty-four hours, divided in three doses, was quite effective during the three days following the operation and caused no complications.

With reference, finally, to the difficulties in arresting the bleeding, Lindgren recommends a 0.5 per cent thionin solution, which is nontoxic. If swabs of cotton wool dampened in this solution and pressed against the bleeding spot do not produce the desired effect, it can be covered with a piece of muscle soaked in the solution, which heals and produces a reliable hemostasis. Intravenous injections of protamine are said completely to counteract the effect of heparin (Jorpes). However, the general effect of the heparin, which is desired, is, of course, also eliminated, and it is thus better if purely local hemostatic arrangements can be made.

SUMMARY

An uncommon case of embolectomy of the common femoral artery has been reported. It is remarkable, *inter alia*, in the following respects: The embolism emanated from a pulmonary vein. The embolus consisted mainly of a sarcoma. Together with the embolus there was extracted a postembolic thrombus, approximately 80 cm. long. Repeated arteriotomies and removals of re-formed clots and intra-arterial injections of eupaverin only produced temporary circulation, which was definitely restored when the artery had been cleaned out for the fifth time followed by an intra-arterial injection of heparin. The heparinization entailed no trouble. The source of the embolism and the treatment are discussed. Embolism in the lower limbs should be subjected to operative treatment, especially if tumor embolism is suspected. The limited clinical experience so far gained of heparinization in cases of embolectomy would seem to promise a better prognosis, there now being better prospects of mastering secondary thrombosis. Cautious heparinization should be performed after each embolectomy. The right moment for heparinization is when the artery has been cleaned and the incision sutured. Preoperative heparinization should be avoided as it entails unnecessary risks of complications.

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ANEURYSM OF THE SPLENIC ARTERY

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ANEURYSM of the splenic artery is rarely diagnosed during life. Schroeder recorded twenty cases in 32,768 post-mortem examinations (once in approximately 1,500 autopsies). In statistics of 41,437 autopsies summarized by Lindboe, there were 554 abdominal aneurysms, of which only 26 (0.05 per cent) were located in the splenic artery. Anderson and Gray collected fifty-eight cases in 1929 and presented a review of the symptomatology and literature. More recently Guy and also Seids and Hauser have reviewed the literature and added cases of their own. There are on record only eleven cases in which the patients have survived operation for this condition. Less than one hundred cases have been recorded since the report of Crisp in 1847.

In the Department of Pathology of the University of Minnesota, there are records of 33,810 autopsies to January, 1939. In this series, there were 393 aneurysms, seventy of which were located in the abdomen. Forty-eight involved the abdominal aorta; of these, twenty-six were ruptured. There were nine aneurysms of the iliac vessels, seven of the splenic artery, two each of the celiac and renal arteries, and one each involving the hepatic and superior mesenteric arteries. Six of the seven aneurysms involving the splenic artery were incidental findings at autopsy; and one had ruptured to cause death. All were described as arteriosclerotic in origin. Syphilis was not noted as an etiological factor in any of these cases.

Surgical removal of aneurysm of the splenic artery has been reported by Winckler, Mulley, Davis, Goulliod, Brockman, Lower and Farrell, Lindboe, and Parsons. According to Winckler, Selten was the first to operate upon one successfully. Marshall obtained a cure by proximal and distal ligation of the aneurysmal sac. Seids and Hauser (1940) reported another cure by ligation.

A correct preoperative diagnosis has been made in only three cases up to the present time. Högler made the diagnosis on the basis of (1) left upper quadrant pain, (2) a systolic bruit over a palpable tumor mass, and (3) a pulsating filling defect in the greater curvature of the stomach. Lindboe made the correct preoperative diagnosis by means of the roentgenogram. He states that aneurysm of the splenic artery can be recognized by roentgen ray only when it is calcified. Seids and Hauser's case presented a palpable mass, a bruit, and, roentgenographically, a calcified area 9 cm. in diameter and medial to the spleen.

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The case presented here exhibited the x-ray findings referred to by Lindboe as suggestive of aneurysm of the splenic artery, i.e., a calcified shadow situated in the left upper quadrant of the abdomen, overlying and projecting to the left of the twelfth thoracic vertebra.

Because of the rarity of the condition, and in the interest of more accurate preoperative diagnosis, it seems worth while to report in detail a case in which the possibility of aneurysm of the splenic artery was considered preoperatively. Recovery followed splenectomy and removal of the aneurysm.

Fig. 1*A*.—Roentgenogram of the left upper quadrant of the abdomen, showing the shadow of a calcified aneurysm of the splenic artery.

CASE REPORT

Mrs. P. W., a married white female, 39 years old, University Hospital No. 661247, was admitted on Aug. 13, 1937, and discharged on Oct. 22, 1937.

Past History.—The patient had had cholecystectomy, appendectomy, and hemorrhoidectomy in 1932, and a right nephrectomy in 1933 for pyelonephritis and stone.

Since 1934 there had been repeated attacks of left pyelonephritis. Artificial menopause in 1935 followed radiation for menorrhagia.

Present History.—Since May, 1937, the patient had experienced recurrent attacks of severe colicky pain in the region of the upper end of the scar of the old cholecystectomy. This pain radiated to the right scapula. There had been anorexia and vomiting and alternating constipation and diarrhea. She had lost 40 pounds.

Examination revealed a blood pressure of 140/94. There was moderate tenderness over the upper end of the scar of the cholecystectomy and in the left flank. No masses were palpable in the abdomen, nor was a bruit to be heard. Rectal and proctoscopic examinations were negative. There was a scanty purulent bloody vaginal discharge. The uterus was situated anteriorly, freely movable, and slightly smaller than normal. There were no adnexal masses.

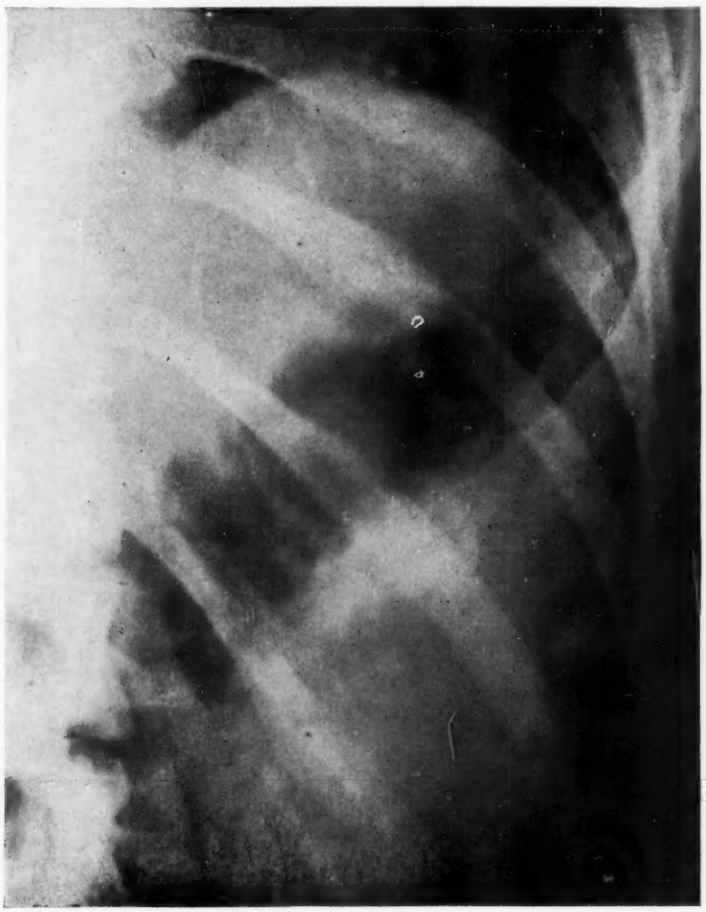

Fig. 1*B*.—Roentgenogram of the left upper quadrant of the abdomen after operation; the shadow is no longer present.

The catheterized urine contained a heavy cloud of albumin and a few granular casts and was sterile. The hemoglobin was 98 per cent, and the white blood count and differential were normal. The Wassermann reaction was negative. The stools contained neither occult blood nor parasites; the icterus index was 11. Gastric analysis showed no free acid. Material aspirated from the duodenum following the administration of magnesium sulfate did not reveal any cholesterol crystals. The

phenolsulphonephthalein excretion was 46 per cent in two hours; the sedimentation rate was normal. Skin tests for echinococcosis were negative.

There was some disturbance of glucose tolerance as evidenced by the following blood sugar values after a test meal: at thirty minutes, 124 mg.; at one hour, 204 mg.; at two hours, 165 mg.

Roentgenologic study of the gastrointestinal tract was entirely negative. There was a dense shadow just to the left of the spine at the level of the twelfth dorsal vertebra. The exact nature of this density was not determined by the roentgenologist, who suggested the possibility of a calcified cyst (echinococcus) in the left lobe of the liver or an atypical calculus in the tail of the pancreas. The dense shadow was found to be behind the stomach and above the left adrenal and kidney. Excretory urograms revealed a normal left renal pelvis, ureter, and bladder.

Fig. 2.—Gross specimen of the excised spleen and calcified aneurysm of the splenic artery.

Because of the disturbance of the glucose tolerance and the location of the calcification, the diagnosis of a calcified pancreatic cyst was suggested by the medical consultant. The urologic consultant thought that the pain was unrelated to the urinary tract. The possibility of a calcified aneurysm of the splenic artery was suggested by Dr. O. H. Wangensteen on the basis of the roentgenologic findings.

The pain was definitely relieved by the administration of nitroglycerin and temporarily relieved by infiltration of the abdominal wall with procain. The patient's condition grew worse because of continued vomiting, and on Sept. 23, 1937, the abdomen was explored by Dr. O. H. Wangensteen.

Operative Findings.—"When the abdomen was opened, there were dense adhesions from the omentum to the entire right abdominal wall anteriorly and laterally. The common duct was retracted somewhat medially, but was normal in size and consistency. The ovaries were pea-sized on both sides. The pelvis was otherwise negative. There was a large pulsating mass in the hilum of the spleen."

Operative Procedure.—"When the stomach had been separated from the upper pole of the spleen, a large dense mass was found intimately related to the splenic artery and medial surface of the spleen. The gastrosplenic omentum and the lienorenal and vascular ligaments were divided, and the spleen was delivered into the wound. It was evident that the hard mass was part of the splenic artery. The latter was clamped proximal to the mass, which was then removed with the spleen. The patient stood the operative procedure nicely."

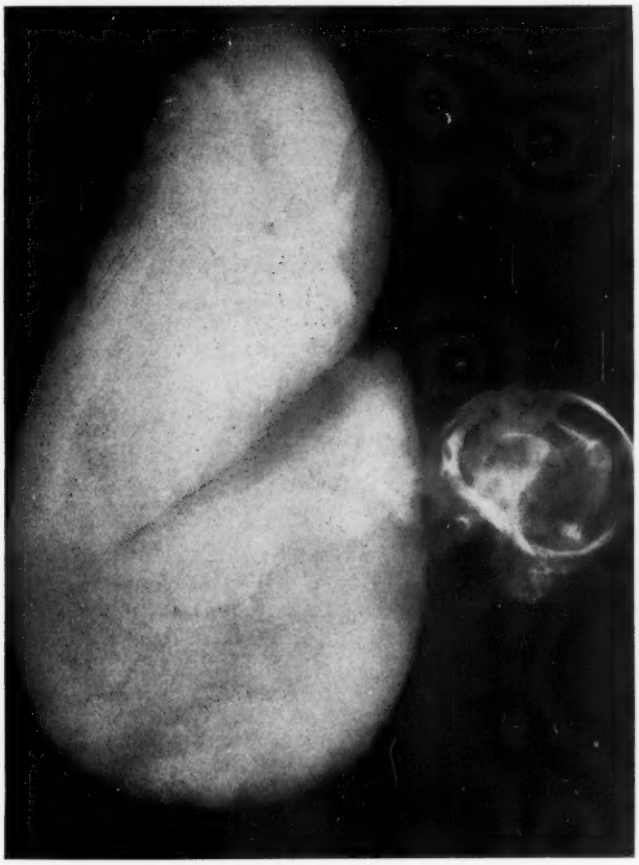

Fig. 3.—Roentgenogram of the excised specimen.

Pathologic Report.—"The spleen itself is approximately normal in size. The splenic artery has been cut about 4 cm. from its bifurcation, at which there is an aneurysm measuring 2 cm. in diameter. The aneurysm projects from the surface of the artery as the closed end of a U, and its walls are thin, slightly lobulated on the internal surface, and heavily infiltrated with calcareous material. On one of the branches of the splenic artery beyond the bifurcation there is a similar but smaller aneurysm measuring about 5 mm. in diameter and about 1 cm. in length. The aneurysm was not dissected but was preserved for a museum specimen."

Conclusion.—Arteriosclerotic aneurysm of the splenic artery.

The patient had an uneventful convalescence from her operation and was discharged from the hospital on Oct. 22, 1937. In August, 1938, the patient had no complaints.

SUMMARY

A calcified aneurysm of the splenic artery is reported. The classical roentgenologic picture described by Lindboe was present and led to a correct preoperative diagnosis. The aneurysm was excised, together with the spleen, and the patient made an uneventful recovery. This is the twelfth recorded instance in which the patient recovered from operation for aneurysm of the splenic artery. Seven additional cases recorded in the autopsy material (33,810 autopsies) of the Department of Pathology of the University of Minnesota are added to those previously reported in the literature.

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CAVERNOUS HEMANGIOMA OF THE SPLEEN

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CAVERNOUS hemangioma of the spleen is an uncommon disease. The rupture of a cavernous hemangiomatous spleen successfully treated by emergency splenectomy has not been reported previously as far as we have been able to ascertain. In 1938, Akcakoyunlu reported a collected series, including one of his own, of twenty-one cases of benign hemangioma of the spleen, and in only one was there an emergency due to rupture of the spleen.[1] In 1933, Haines and McIlroy reported the single case of spontaneous rupture of the spleen.[2] Their patient was a white married woman 43 years of age, who, twenty-four hours prior to hospital admission and unassociated with trauma, was seized with extremely severe pain in the epigastrium. Nausea and vomiting soon followed. The pain was localized chiefly in the epigastrium, but was present to a moderate degree in the right lower quadrant. Physical examination disclosed the patient to be semicomatose and gasping for air, "the entire abdomen was tender, exquisitely tender in the epigastrium and moderately tender in both upper quadrants."[2] A tentative diagnosis of an acute perforation of a gastric ulcer was made and immediate operation was performed. The peritoneal cavity contained a large quantity of bright red blood; the spleen was surrounded by fresh adhesions, and the organ was removed. Near the upper pole of the spleen a collection of cystlike spaces containing blood was present, and the largest of these had ruptured. Death occurred forty-eight hours after the operation. In the case to be reported, splenectomy was performed seventeen hours after the onset of symptoms.

Hemangioma of the spleen is a primary vascular tumor and may be either capillary or cavernous. In the former there is a formation of dilated vascular channels in the splenic tissue which gradually become converted into tubules. In the cavernous type the capillary system is lost, and the hemangioma consists of a series of freely intercommunicating spaces of varied sizes, lined with endothelium. Ordinarily, they are considered congenital. The published case reports are confusing in that several are described as malignant neoplasms metastasizing to adjoining organs, especially the liver. This is true in the cases reported by Langhans (1879),[3] Homans (1897),[4] Theile (1904),[5] Wright (1928),[6] and

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Dowd (1915).[7] In 1895, Hodge stated, "Apparently all gradations occur from single localized or widely diffuse telangiectatic changes to more or less encapsulated angiomatous nodules, and finally to highly malignant tumors with metastasis."[8] Abrams recently has reported a most interesting case of a "histologically benign metastasizing hemangioma involving spleen, liver, kidneys, pancreas, adrenals, intima of the pulmonary artery, the right lung, and the mesenteric, peripancreatic, preaortic, and mediastinal lymph nodes."[9] Matas described the behavior of angiomas of the spleen as characteristic of that of a benign neoplasm.[10]

The benign hemangiomatous spleen may reach an enormous size. Akcakoyunlu reported a case treated by splenectomy, with recovery, in which the spleen weighed 7,240 Gm.[1] Zeno and Cid report recovery following splenectomy of an angiomatous spleen weighing 5,800 Gm.[11] Steden reported a similar case in which the spleen weighed 4,812 Gm.[12] Ordinarily, the involved spleen is much smaller. The reported cases demonstrate that there is great variance in age, the youngest patient being 4 months and the oldest, 65 years. Usually the symptoms are of several months' or years' duration and are characterized by a gradually increasing tumefaction in the left hypochondrium, associated with pain, loss of weight, and anemia. Thus, ample time is available for a thorough clinical study prior to operation. Surgery is the only curative therapy, and splenectomy is necessary.

The reported cases of benign hemangioma of the spleen are tabulated in Table I. A total of twenty-two cases has been reported previously. We wish to add a case report to this list. Schottenfeld and Wolfson state that the records of the Jewish Hospital, Brooklyn, show that four additional cases of small splenic hemangiomas were discovered at necropsy which had not given symptoms during life, but data on these cases are not furnished.[13]

CASE REPORT

An army officer, white, aged 27 years, was admitted to the Walter Reed General Hospital on May 1, 1939, complaining of the sudden onset of moderate intermittent cramplike pain in the upper abdomen thirteen hours prior to admission. Within one hour after the onset he drove his automobile twenty-two miles, but the trip was temporarily interrupted because of vomiting and increased pain. He slept intermittently from 1:00 to 5:30 A.M., and by that time the pain was violent, although it remained cramplike in character, being increased by deep respirations and on turning from side to side. There was no further vomiting. The pain continued and was localized chiefly across the upper abdomen, but it involved the entire abdomen. Previous significant history included an acute attack of severe pain in the left upper abdomen and back on Sept. 13, 1938, which subsided rapidly without clinical investigation. On March 27, 1939, the patient was thrown from a horse and suffered slight pain in the left hypochondrium and beneath the corresponding lower ribs. He was able to ride horseback the following day and continued his work uninterruptedly.

On physical examination, the patient was rational, lying quietly in bed, and in apparent pain. The temperature was 98° F.; pulse, 80; respiration, 20; and blood pressure, 140/80. The abdomen was distended slightly and was moderately tender

TABLE I*

COLLECTED CASE REPORTS OF BENIGN HEMANGIOMA OF THE SPLEEN

AUTHOR	SEX	AGE	DURATION	SYMPTOMS	OPERATION	RESULT	DIAGNOSIS
Hodge, Jr.	F	43	4 yr.	Abdominal mass; constipation; diarrhea; loss of weight	Splenectomy	Cured	Cavernous hemangioma
Martin and Ombrendanne	F	31	Months	Pain; abdominal mass; constipation; loss of weight	Splenectomy	Cured	Angioma
Albrecht	M	65	–	Autopsy report	–	–	Cavernous hemangioma
Theile	M	22	–	Autopsy report	–	–	Obliterating angioma
	M	36	–	Autopsy report	–	–	Obliterating angioma
	M	62	–	Autopsy report	–	–	Obliterating angioma
V. Benkendroff	M	53	2 yr.	Abdominal mass	Splenectomy	Not reported	Cavernous hemangioma
Angilotti	F	38	14 mo.	Pain; vomiting	Splenectomy	Cured	Cavernous hemangioma
Muller	M	30	–	Autopsy report	–	–	Capillary angioma
Steden	M	42	8 yr.	Abdominal swelling, left	Splenectomy	Cured	Cavernous hemangioma
Orlandi	F	44	1 yr.	Fatigue; edema of extremities	Splenectomy	Died 3 hours later	Cavernous hemangioma
Schwartz	F	35	4 mo.	Pain; abdominal swelling, left upper quadrant	Splenectomy	Cured	Cavernous hemangioma
Zeno and Cid	M	30	5 mo.	Loss of weight; abdominal mass; fatigue	Splenectomy	Cured	Hemangioma endothelioma
Wassiljeff and Pratassewitch	M	32	1 mo.	Swelling, left hypochondrium	Splenectomy	Cured	Capillary hemangioma
Kellert	F	52	–	Abdominal mass; chill; fever	Splenectomy	Cured	Cavernous hemangioma
Palvecino, Villegas, and Palazon	M	41	20 yr.	Abdominal swelling	Splenectomy	Cured	Angiomatosis
Haines and McIlroy	F	43	–	Sudden severe epigastric pain; nausea; vomiting	Splenectomy	Died 48 hours later	Spontaneous rupture of cavernous hemangioma
Grove	F	4 mo.	Congenital	Abdominal mass; vomiting; constipation	Splenectomy	Cured	Fibroangioma
Milami	F	45	–	Autopsy report	–	–	Cavernous hemangioma
Akcakoyunlu	M	30	3 yr.	Abdominal mass; dyspnea	Splenectomy	Cured	Capillary and cavernous hemangioma
Schottenfeld and Wolfson	F	31	7 yr.	Abdominal mass	Splenectomy	Cured	Cavernous hemangioma
Naher	F	42	5 yr.	Enlargement of abdomen	Splenectomy	Died 30 days later	Hemangioma
Cole and Forsee	M	27	17 hr.	Sudden epigastric pain	Splenectomy	Cured	Rupture of cavernous hemangioma

*Condensed from Akcakoyunlu, with additional case reported by Schottenfeld and Wolfson and the authors' case. See references 1 and 13.

throughout, but with most marked tenderness in the right lower quadrant. The blood picture was as follows: erythrocytes, 4,400,000; hemoglobin, 80 per cent; leucocytes, 15,200, and polymorphoneutrophiles, 84 per cent; coagulation time, 2½ minutes, and bleeding time, 2¼ minutes. The urine analysis was negative. A tentative diagnosis of acute appendicitis was made, and immediate operation was performed. The peritoneum was opened through a McBurney's incision, and blood welled into the wound. Appendectomy was performed although the organ appeared normal. The

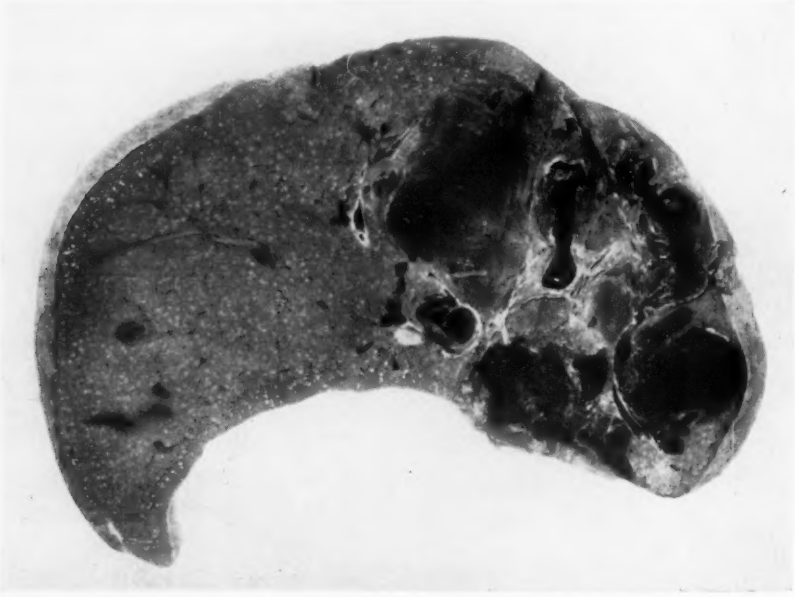

Fig. 1.—Section of spleen showing the cavernous hemangioma. Adherent clot was present over the surface of the angioma space on the concave surface. There is a recent rupture on the right side of the convex surface about midway from bottom to top of the illustration. (U. S. Army Medical Museum, Neg. No. 68675.)

Fig. 2.—Low-power photomicrograph of section through several of the angioma spaces, showing thick fibrous walls and somewhat retracted blood clot in the lumina. Note hemorrhage into tissues at left center. (U. S. Army Medical Museum, Neg. No. 68763.)

McBurney's incision was closed, and a 15 cm. midline upper abdominal incision was made. A large quantity of free blood was evacuated from the peritoneal cavity, and the liver, stomach, and duodenum were found to be normal. On palpation, the spleen was found to have an area at its lower pole which had ruptured, and splenectomy was performed. The postoperative course was uneventful, and the patient left the hospital twenty-three days after operation. Seven months later he was in perfect health.

*Pathologic Report.** *Gross Findings.*—The specimen (Fig. 1) is a spleen weighing 225 gm., preserved in formalin solution. The lower pole, about one-third of the spleen structure, is composed of multiple more or less spherical nodules, from 0.5 to 3.0 cm. in diameter, filled with dark, formalin-fixed blood. There is a lacerated wound 1.5 cm. long and 0.4 cm. wide on the external surface, about 3 cm. from the margin. There is no reaction about this wound. On the inner surface of the lower pole there is an open lacerated area, 3 cm. in length by about 1.5 cm. in diameter, covered with an adherent dark clot. The rest of the splenic tissue appears essentially normal.

Microexamination.—Sections from the main splenic tissue are essentially normal (Fig. 2). Sections from the lobulated areas show them to be composed of dense fibrous walls lined in occasional areas with endothelium. Most of the lobules, however, show fairly recent clot beginning to undergo organization by fibroblastic proliferation from the wall.

The *diagnosis* was cavernous hemangioma of the spleen with rupture of part of the tumor.

SUMMARY

A case of ruptured cavernous hemangioma of the spleen, mistakenly diagnosed as acute appendicitis, which was successfully treated by splenectomy is recorded. No similar case report in which the patient recovered has been found in the literature. The recorded cases of benign hemangioma of the spleen have been tabulated and brought up to date, the list containing twenty-three cases.

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FURTHER STUDIES OF HEMORRHAGE AND SERUM INFUSION

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IN A previous paper[1] we demonstrated that severe shock from hemorrhage requires prompt restoration of circulating fluid volume and that immediate restitution of red blood cells is of only secondary importance in most cases. We were able to demonstrate that serum is a good substitute for whole blood and pointed out that it has certain advantages which make it more useful and practical than blood. Sterile pooled serum can be kept ready for immediate use for long periods of time[2] and may be infused in large amounts without preliminary typing or compatibility tests.

In the experiments reported in our previous paper we transfused dogs following hemorrhage with amounts of blood, serum, saline or glucose solution equal to the total amount of blood lost by bleeding. For very practical reasons we were interested in finding out experimentally whether infusion with amounts of serum smaller than the volume of blood lost in hemorrhage would give satisfactory results in combatting shock and how such infusions of serum would compare with infusions of whole blood. Johnson and Blalock[3] showed that in dogs the removal of whole blood is tolerated better than the loss either of blood plasma or of red cells.

Experimental Procedure.—This has been described in detail previously[1] and is only briefly recapitulated here. Under light ether anesthesia the right carotid artery and jugular vein were isolated and cannulated aseptically. Three hours were permitted to elapse to allow the animal to recover from the effects of anesthesia. Blood pressure, pulse, respiration and temperature, red blood cell count, hemoglobin, hematocrit, blood CO_2, O_2, N.P.N., plasma proteins and chlorides were determined before every bleeding. Certain of the above determinations were repeated at more frequent intervals. Blood pressure was measured with a tycos anaeroid gauge connected to the carotid artery. The animals were infused through the jugular vein at a uniform rate of 20 c.c. per minute with their own citrated blood removed at the preceding bleeding or with the serum of other dogs. Compatibility tests were done and only compatible serum used.[4] At the termination of each experiment, the cannulae were removed, the wounds dressed, and the animal returned to its cage.

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Bleeding was performed at a uniform rate of 25 c.c. per minute. Thirty per cent of the calculated circulating blood volume* was removed and thirty minutes later blood or serum was administered. One-half hour later the next bleeding took place. This procedure was repeated until the animal had been bled of 80 per cent of the calculated circulating blood volume in successive stages of 30, 20, 20, and 10 per cent. In those dogs reinfused with serum the actual cell volume removed was only 66.6 per cent, due to progressive dilution of the blood by the serum infusions. The amount of blood or serum reinfused was equivalent only to the plasma volume removed at the preceding bleeding; thus the decrease in volume from loss of the cellular elements was not restored. Furthermore, there was no restitution of the blood removed for chemical determinations, etc., totaling 125 to 175 c.c. in each experiment.

Results.—Sixteen experiments were performed, eight dogs receiving their own citrated whole blood and eight others receiving dog serum. The results are summarized in Table I.

TABLE I

	NO. OF EXPERIMENTS	SURVIVAL	AVERAGE BLOOD PRESSURE		AVERAGE BLOOD CHEMICAL DETERMINATIONS				REMARKS
					INITIAL / FINAL				
			INITIAL	FINAL	CO_2	CL.	N.P.N.	PROTEIN	
Serum-infused dogs	8	6	153 / 99	111 / 71	37.3 / 36.1	606 / 623	29 / 29	6.2 / 5.9	As judged by clinical condition, the surviving serum-infused dogs were in somewhat better physical status than the surviving whole blood-infused dogs
Whole blood-infused dogs	8	7	149 / 96	102 / 75	36.1 / 32.4	654 / 662	28 / 29	5.8 / 4.9	

Dogs reinfused with blood received an average of 60 per cent of the total blood removed (54 to 74 per cent). Dogs reinfused with serum received an average of 68 per cent of the volume of blood removed by hemorrhage (64 to 71 per cent). The latter group† received more fluid in reinfusions than did the former because in the successive bleedings and reinfusions with serum the proportion of serum to corpuscular elements increased.

One blood dog and two serum dogs died during the course of the experiments. This contrasts unfavorably with results reported in our first paper in which complete volume restoration was done and in which

*The literature contains values for blood volume of dogs which vary from 7.5 to 11 per cent of body weight. We arbitrarily chose the figure of 7.5 per cent of body weight as representing the circulating blood volume of the dog.[5]

†For brevity dogs infused with blood or serum are designated as blood dogs or serum dogs respectively.

all animals survived. Both groups of animals showed comparable falls in blood pressure during the course of the experiments, and the final blood pressure readings one-half hour after the fourth infusion disclosed that the serum group had an average blood pressure value of 111/71 compared with a value of 102/75 for the whole blood-infused dogs.

The chemical determinations revealed a small drop in the alkali reserve and a decrease in the plasma protein value of the blood dogs. The latter decrease cannot be due to diluting effects of citrate because a concentrated solution was employed as anticoagulant. It may be due to the fact explained above that the blood dogs received less total reinfusion than did the serum dogs.

Erythrocyte count, hemoglobin and hematocrit values dropped 10 to 20 per cent in the blood dogs and 40 to 60 per cent in the serum dogs. The pulse rate was increased in both groups of dogs, being somewhat higher in the serum dogs than in the blood dogs.

DISCUSSION

Our data show that reinfusion with amounts of blood or serum smaller than that lost by hemorrhage did not save the life of all animals, while in previous work reinfusion with amounts of blood or serum equal to that lost kept all animals alive. There are no accurate or rapid methods of determining the amount of blood lost in massive continuous or repeated hemorrhage in human beings. Since incomplete restoration of volume by either blood or serum is not as effective or as lifesaving as complete restoration, it would seem advisable that maximal rather than minimal quantities of serum or blood should be administered. We must take into consideration the arguments against infusion in conditions like bleeding ulcer where infusion which sustains the blood pressure may also counteract spontaneous cessation of hemorrhage. It is not our purpose here to enter into a discussion of the pros and cons of infusion in such circumstances, but it should be pointed out that, if the hemorrhage has been excessive, a fatal outcome from shock is probable and it must be combatted by transfusion to maintain an adequate circulating blood volume. Furthermore, our results indicate that serum infusion seems to be as beneficial as whole blood even if there is only partial replacement of volume following graded massive hemorrhage. The anemia produced in the serum dogs as noted previously caused no distress and the animals showed no evidence of anoxia or acidosis. The general physical condition of the serum dogs surviving the experiments seemed slightly better than that of the blood dogs, possibly due to the fact that they had received a somewhat larger amount of fluid.

Table II, presented for contrast, shows the results obtained in our previous work[1] in which amounts of blood or serum equal to the total volume of blood (plasma plus cells) lost in hemorrhage were reinfused. These animals had a higher final blood pressure and slightly better CO_2

and protein values than the animals presented in this paper. We must attribute part of the drop of blood pressure in all the experiments to the long duration of these experiments. The dogs in our previous experiments were in better physical condition at the end of the experiment than those presented in the present paper.

TABLE II

INFUSION WITH	NO. OF EXPERIMENTS	SURVIVAL	AVERAGE BLOOD PRESSURE		AVERAGE BLOOD CHEMICAL DETERMINATIONS	
					INITIAL	
					FINAL	
			INITIAL	FINAL	CO_2	PROTEIN
Serum	12	12	158	128	39.0	6.6
			105	77	38.5	6.4
Blood	5	5	178	137	36.9	6.2
			108	97	34.3	5.3

SUMMARY AND CONCLUSIONS

Successive hemorrhages in dogs and only partial restoration with serum or blood does not permit survival of all animals, while reinfusion with amounts of serum or blood equal to the total volume of blood lost preserved the life of the animal in each instance. Our experiments show that serum and blood are of nearly equal value when transfusing amounts smaller than those lost in graded massive hemorrhages. In shock from massive hemorrhage maximal rather than minimal amounts of serum or blood should be administered.

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SUBDIAPHRAGMATIC (PERIRENAL) EXTENSION OF STAPHYLOCOCCIC EMPYEMA

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TRANSDIAPHRAGMATIC and retrodiaphragmatic extension of infections comprise a subject of considerable interest. There are numerous accounts of infections beginning beneath the diaphragm either in the intraperitoneal spaces or in the perinephric region which have traversed the diaphragmatic barrier and induced pleural and pulmonary complications. Ochsner and DeBakey,[1] in a comprehensive review of the subject of subphrenic abscess, found that 63 per cent of their cases had pleural or pulmonary complications. Hochberg[2] stated that 85 per cent of 111 cases of subphrenic abscess presented thoracic complications, and that in 45 per cent of these the symptoms at the onset were referable to the thorax. Nesbit and Keene[3] reported a series of cases of perinephric abscess which perforated into the bronchial tree. Beye[4] recorded 31 cases of subphrenic (intraperitoneal) infection of which 23 had thoracic complications, and also 8 cases of perinephric abscess with similar complications. On the other hand, his review of a series of 337 cases of empyema revealed only 1 in which a subphrenic abscess was caused by extension of the infection from the pleura, and in that case the diaphragm was injured at the time of operation. Beye's conclusion is that the diaphragm is an efficient barrier against extension of infection from the thorax to the abdomen.

The evidence therefore points to the rarity of invasion of the subphrenic space by an empyema. It is interesting to note that Osler,[5] in his discussion of empyema and perforation of the diaphragm, states that it is often difficult to tell on which side of the diaphragm the infection begins. He cites the presence of peritonitis, either general or local, in 9 of 38 autopsies on cases of empyema. He adds: "An abdominal abscess, starting from the pleura, may perforate the stomach, the intestines, or the kidney. It may extend along the spine to the iliac fossa and simulate a psoas or lumbar abscess."

The possible subphrenic pathways were surveyed by Lillienthal.[6] He states that a chronic empyema "may invade any of the contiguous body spaces by perforating directly through structures bounding those spaces, notably the diaphragm. It may perforate into the hollow viscera of the abdomen, the stomach and intestines, the liver, etc."

There are a number of specific instances of the above which have been reported and can be briefly reviewed. Deane[7] describes a case of empyema necessitatis which pointed in the loin. Dyson[8] placed on record a

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case of empyema with diaphragmatic perforation and gastropleural fistula, in which the possibility of operative injury to the diaphragm was admitted but was considered unlikely. Harzbecker[9] reported a case of empyema in a patient with a long history of cough and expectoration. Following drainage of the empyema, a large perinephric abscess extending up to the eleventh rib on the same side was discovered. Since no direct communication was demonstrable between the perinephric abscess and the already healing empyema, Harzbecker considered the perinephric abscess to be metastatic from the original bronchiectasis. Tees[10] reported a case in which a lumbar abscess could be traced directly to an acute infrapulmonary empyema. He also mentions a similar case report by Fagge and Smith. Swan,[11] in his review of 114 cases of subphrenic abscess, cites one case in which the infection was of pleural origin.

The following is the report of a case which apparently belongs to the group of pleural infections which have penetrated or extended behind the diaphragm to involve subdiaphragmatic structures. The chief purpose in reporting this interesting case is to survey the pathways of extension across the diaphragm.

CASE REPORT

The patient was a 48-year-old housewife, complaining of right loin pain, fever, and weakness. Her past history included an appendectomy and a right salpingo-oophorectomy twenty-two years before, a right pleurisy seventeen years before, and osteoarthritis sixteen years prior to her present admission. One year ago she had severe pain in her back on the right side which incapacitated her for several days. Ten weeks prior to the onset of the present illness, there were a number of furuncles and small carbuncles about the neck and axillae, the last of which healed a few weeks before this illness began. During this time several badly infected teeth were removed and a moderately severe gingival infection was treated.

The present illness began seven weeks before admission to the hospital, with chills and pain in the right lower chest. Signs of consolidation appeared over the right lower lobe. For several days she ran a course typical of lobar pneumonia with chest pain, tachypnea, fever, and slight cyanosis. The diagnosis was made by her physician and confirmed by consultants. Cough was minimal, and the sputum scanty, colorless, odorless, and tenaceous. Pneumococcus type XI was recovered from the sputum by mouse typing on two occasions. By the fifth day the signs over the right lower lobe had changed from dullness and bronchial breathing to flatness and diminished breath sounds. There was some amelioration of symptoms on the seventh day, but the temperature rose again that night. From that time on fever ranged between 101 and 104°. Tachypnea was persistent. Two thoracenteses were done. Seventy-five cubic centimeters of fluid, containing few white cells and no organisms, were obtained the first time. No fluid was obtained on the second tap. The chest signs were quite constantly dullness to flatness, diminished breath sounds, and a few râles at the right base. Two roentgenograms were taken. The first, after three weeks, showed some elevation of the right diaphragm and cloudiness in the right cardiophrenic angle and interlobar fissure. The second, taken after five weeks, revealed some resolution of the cloudiness, but the diaphragm remained elevated. About one and one-half weeks prior to admission, pain in the right flank appeared and became progressively more severe up to the time of admission.

Physical examination revealed a pale, acutely ill woman. Temperature was 102.6°; respiration, 30; pulse, 112. There was dullness to flatness at the right base with diminished breath sounds over that area. There was extreme tenderness in the right costovertebral angle. The fingers were not clubbed; the abdomen was negative. W.B.C., 16,600 with 84 per cent P.M.N.; 15 per cent lymphocytes and 1 per cent mononuclears; Hg., 48 per cent; urine contained only a few white cells. Chest x-ray revealed a dense shadow in the right lower chest which was interpreted as fluid dipping beneath the base of the lung. The portion of the right lung that was visualized and the entire left lung showed no abnormalities.

The chest was aspirated in the right eighth intercostal space and a small amount of pus was obtained.

Operation was performed under avertin-nitrous oxide-oxygen anesthesia. An incision was made over the ninth rib below the angle of the scapula and that portion of the rib excised. The pleura posteriorly seemed inflamed. Several aspirations were made at this time; some bloody fluid was obtained; but pus was not encountered. A cautious incision through the inflamed pleura revealed the lung immediately subjacent and adherent to the parietal pleura. An additional section of the posterior portion of the ninth rib was excised, revealing thick edematous pleura. Pus was then encountered at the lower medial margin of the operative field arising from under the tenth rib. Purulent exudate was found tracking beneath the tenth and eleventh ribs. The overlying portions of these two ribs were removed and a cavity was found which extended at least three to four inches below the eleventh rib. The cavity was about one inch in diameter and lined with purulent slough. From the walls of the cavity pus could be expressed. A tract was then discovered at the level of the tenth rib extending anteriorly. Digital examination of this tract revealed the smooth upper border of a rounded mass and some fleshy tissue was removed for examination from the depths of this anterior sinus. No further loculations were found and the entire cavity was packed. Culture of the pus was *Staphylococcus aureus*. Microscopic examination of the tissue removed (Dr. P. Klemperer) was as follows: Fragments of kidney showing leucocytic infiltration of the stroma with atrophy of the tubules and many leucocytes within the tubules; histology suggestive of pyelonephritis (see the history of an episode of right loin pain one year previous).

The postoperative course was one of progressive improvement. X-ray of the chest on the fifteenth postoperative day still showed some elevation and haziness of the diaphragm and slight thickening of the short fissure. Repeated urine examinations revealed only faint traces of albumin at times and occasional white cells. Culture of the urine was reported enterococcus. The patient was discharged with a clean granulating wound and normal temperature.

The interpretation of the pathogenesis in this case admits of several possibilities. The following statements appear warranted: the culture of the pus was staphylococcus and the abscess was therefore presumably metastatic from the previous skin lesions; there was a spread of the infection through or behind the diaphragm; both the pleural and the perinephric spaces were invaded. In view of the acute onset with chills, fever, chest pain, and lung findings, in addition to the tardy appearance of loin pain, the supradiaphragmatic lesion was probably primary, and the perinephric space and kidney were secondarily invaded.

The lesion in the lung itself was probably a metastatic subpleural abscess with an area of consolidation about it. This type of lesion induces an early pleural reaction which tends to form adhesions between

the parietal and visceral pleura, thus sealing off the infection from the general pleural cavity. Neuhof and Berck,[13] in their studies of staphylococcus empyema, describe this type of lesion in adults. They state that in these patients the pleural reaction tends to be that of a sacculated empyema or pyopneumothorax in contradistinction to the subtotal or total empyema or pyopneumothorax as found in children where firm pleural adhesions fail to form early.

Given then a sacculated empyema, the next phase was perforation of the parietal pleura, peripleural extension, and invasion of the diaphragm or dissection behind that structure. The appearance of loin pain on about the fortieth day was apparently the signal of spread of the infection downward. The consideration of the pathways along which such a spread might take place is a matter of clinical as well as anatomical interest.

Obviously a suppurative process on one side of the diaphragm may reach structures on the other side by direct spread in only one of two ways, either by penetrating that organ or skirting its attachments. Direct invasion through the diaphragm occurs at first via the lymphatics, and later, with more severe infection, gross invasion of the musculature takes place with actual perforation.[4] The normal lymphatic drainage in this region is directed upward, which is one of the factors accounting for the frequency of thoracic complications following subphrenic infection. Given, however, a suppurative process in the chest with blocked lymphatics above the diaphragm, retrograde lymphatic drainage from above downward can occur.[2]

Potential avenues of communication between the thorax and the abdomen are present in the connective tissue about the various structures that traverse the diaphragm. For example, the space between the aorta and the diaphragmatic crura is filled with loose areolar tissue continuous with the mediastinum above and the retroperitoneal tissues below. Pathways exist for the spread of infection along the course of other structures, such as the superior epigastric artery passing between the costal and sternal diaphragmatic attachments, the musculophrenic artery between its attachments to the seventh and eighth ribs, the vena cava, and the esophagus.[14]

Instead of penetrating the diaphragm, an infection may spread around its attachments. The possible anatomical pathways are of interest and in the past have received scant attention. Posteriorly the pathway might be behind the medial or lateral lumbocostal arches from which the diaphragm takes origin. The lumbocostal arches are fibrous thickenings in the sheaths of the psoas and quadratus lumborum muscles. These muscles arise at a higher level than their arches and, as a result, an infection perforating the parietal pleura in this area comes directly into contact with one of these muscles and may follow the muscle down behind the lumbocostal arches and the muscle sheaths into the lumbar

region.[10] This was the pathway postulated in the case reported by Tees,[10] in which a lumbar abscess could be traced upward to an infrapulmonary empyema. The infection was directed away from the kidney by the sheath of the quadratus lumborum and the thick posterior layer of the renal (Gerota's) fascia. The efficacy of this fascial layer as a barrier against spread of infection toward the kidney was borne out by a case reported by Edelman.[15] An exploratory operation was done for what was thought to be a perinephric abscess. Instead an abscess was found posterior to the posterior layer of the renal fascia, but immediately adjacent to it, and yet the fatty capsule of the kidney, separated only by this posterior layer of renal fascia, was entirely normal.

There is a pathway, however, which would carry a pleural infection anterior to the posterior layer of the renal fascia into direct contact with the kidney. Cunningham[14] states that not infrequently "an interval separates the diaphragmatic fibers arising from the lateral lumbocostal arch from those arising from the medial lumbocostal arch. In these cases the kidney and the lower limit of the pleura are intimately related." In addition in this region the anterior and posterior layers of the renal fascia of Gerota fuse with the diaphragmatic fascia and do not present the distinct layers of thick protecting fascia that they do anteriorly, posteriorly, and laterally.[12] From the operative findings in the case which is the object of this report, it seems most probable that the infection reached the kidney through this defect between the diaphragmatic origins from the two lumbocostal arches.

In the final differential diagnosis of our case certain other possibilities must be mentioned. One interpretation that has the weight of statistical frequency to recommend it is the diagnosis of metastatic cortical abscess of the kidney with secondary perinephric abscess, perforation of the diaphragm, empyema, and pneumonitis. However, a careful analysis of the clinical history makes this diagnosis unsound. The onset of the illness was sudden with prompt appearance of symptoms and signs related to the lung. It was not until almost the sixth week of illness that severe back pain occurred, presumably the effect of spread beneath the diaphragm. Another feature is the fact that, with the exception of the skin and dental infections, the patient was well prior to the onset of this illness; whereas, in those cases of unsuspected subphrenic abscess that have as their first manifestation some supradiaphragmatic complication, there is usually a period of unexplained fever or vague chronic or subacute illness prior to the pulmonary or pleural infection.

There is also the possibility that two distinct illnesses were present, namely, a pneumococcus pneumonia and a staphylococcus renal cortical abscess, that spread upward to invade the pleura. The findings that support such a conclusion are presence of pneumococcus type XI in the sputum and the physical findings resembling lobar pneumonia at the

onset. In our experience we have often found pneumococci of the higher types in the sputum of patients who have lung lesions subsequently proved not to be of pneumococcal origin, especially when the typing is done by the mouse method. By that method, even though there are only a few pneumococci present in the specimen of sputum injected into the peritoneal cavity of the mouse, the growth of those organisms is favored and that of the remaining is inhibited. Consequently that method gives no information as to whether or not the pneumococcus found was the predominant organism or merely one of a number of organisms present in the upper respiratory passages. As far as the prompt appearance of the physical signs of lobar consolidation is concerned, such findings are just as compatible with the picture of a staphylococcus abscess with surrounding pneumonitis as with pneumococcus lobar pneumonia. Finally, the extension of an independent renal and perirenal infection to the exact site of a pneumonic lesion with associated pleuritis would be too unusual a coincidence on which to reckon when a more likely pathogenesis can be offered.

SUMMARY

A case of staphylococcic empyema with extension beneath the diaphragm and about the kidney is presented. The anatomical pathways for spread of infection from the thorax to the subphrenic regions are discussed. Similar cases recorded in the literature are analyzed.

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EXPERIMENTS WITH TAMPONS AND MEMBRANES MADE OF COLLAGEN

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THE use of animal absorbable and assimilable material in surgery has been confined practically to catgut. The use of devitalized connective tissue, recommended by Nageotte,[1] on good theoretical and experimental bases has never become popular. The present development of resistant fiber from dissolved collagen creates the possibility for experimental investigations on absorbable tampons.

The surgical importance of an absorbable or assimilable tampon material is evident. It would no longer be necessary to leave a foreign body in the body disturbing and delaying the healing of the wound by the presence and ultimate removal of an unabsorbable tampon. All the dangers associated with the removal of a tampon, such as injury to the adhering organs, reopening of cavities, spreading of localized infections by rupture of granulation tissue, secondary hemorrhage by tearing away clots of blood, etc., would be obviated and patients would be spared the pain associated with manipulation of tampons. Moreover, the field of application of an absorbable biologic, nonirritating material could be widely extended as compared with that of the tampon now in use. The material, originally intended to be the substance of a new absorbable suture, is obtained from slaughtered cattle. In addition to ligatures and sutures tampons and *plombes* can be made of the same collagen material.

Before testing these tampons surgically, in which we are still engaged, it was necessary to examine the reaction of the organism to the implantation of these collagen fibers and to determine whether the implanted material would behave in the body as a foreign body, or whether it would be absorbed, assimilated, or organized. It was taken for granted that the reaction of the body to the new material would be different from that to catgut. Apart from the devitalization and denaturalization process the material has undergone, the substances of the two materials are quite different, for catgut is made of the smooth muscle tissue of sheep's intestine. In histologic sections using van Gieson's stain, catgut appears yellowish brown. The new material, brocatamp, on the contrary, consists of connective tissue substance, and the collagen reaction reveals a slightly red color to van Gieson's stain. Our first experiments were made exclusively for the purpose of studying the histologic changes of the material in animal tissue and the reaction of this tissue to the implanted material. Each experiment was per-

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formed on at least four animals. The tampon material used was of different consistency. The very light hydrophilic spongy brocatamp was mainly used, as it appeared very effective in arresting hemorrhage from parenchymatous organs (liver). Tampon material soaked in a hemostatic agent (sangostop) was also used successfully. The material is exceedingly plastic and can be compressed into about one-twentieth of its volume. Tampons of greater consistency were employed to stuff large cavities.

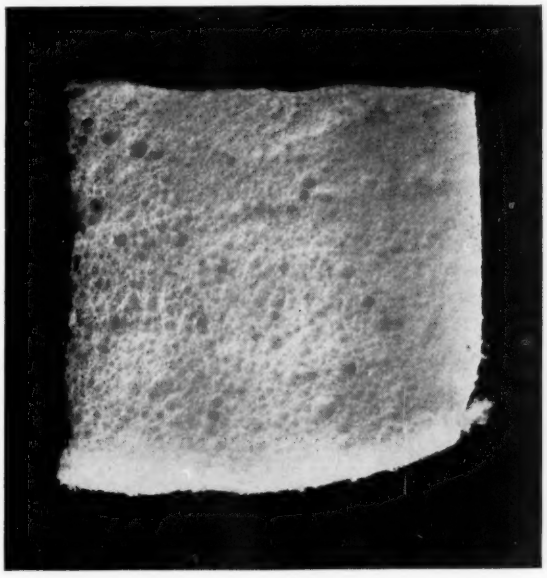

Fig. 1.—Photograph of spongeous tampon material.

There was no apparent difference in the reaction of soft or hard and compressed and noncompressed tampons. Apparently the spongy mass of the tampons soon becomes filled with serum which equalizes the differences. The reaction of the various tissues to the implanted tampons is a very slight one. There seems to be no chemical or mechanical irritation of the surrounding tissue. The collagen which forms the tampon does not act as a foreign body in the organism. The tampons do not become adherent to the surrounding tissue. During the first few days following the implantation, they apparently absorb serum. This is followed by an invasion of leucocytes which extend their phagocytic action along the large surface of the spongy tissue. The wide meshes and openings facilitate the infiltration of granulation tissue from the connective tissue capsule that soon develops around the tampon and is more or less firmly attached to the surrounding structures. Tampons in parenchymatous organs, such as the liver, spleen, kidneys, etc., are fixed; whereas, tampons in muscle, fat, and connective tissue remain loosely attached to their environment by a thin network of connective tissue fibers for considerable time.

The connective tissue capsule of the implanted body is formed by organization of the serum in and around the tampon. Under normal conditions the tampon is not as firmly encapsulated as a foreign body, but rather is infiltrated by granulation tissue and thus gradually organized. Accompanying this process of organization is one of destruction not only by phagocytosis but also by liquefaction. The leucocytes and giant cells particularly show a phagocytic activity. The latter appear as syncytial formations of connective tissuelike origin. They are often seen pressed close to the fibers of the implanted material or

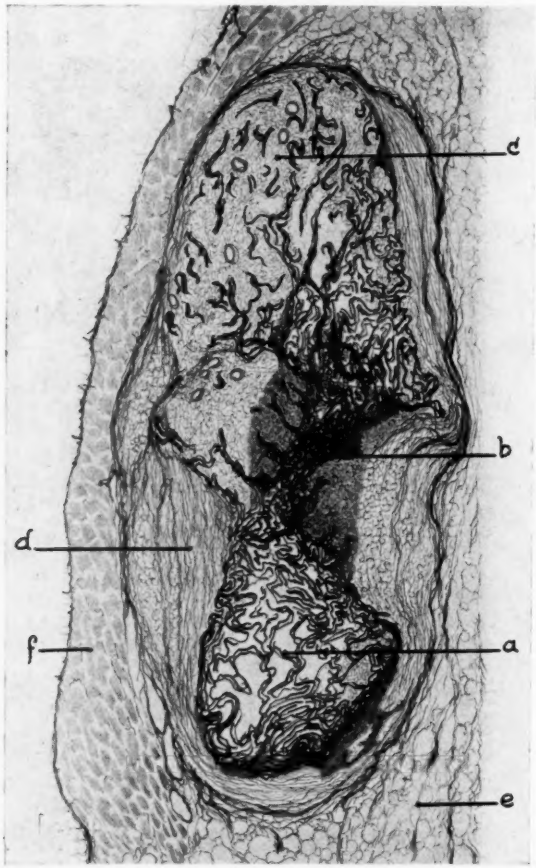

Fig. 2.—Appearance on microscopic examination of implanted tampon. The entire tampon rest is surrounded by a fibrillar connective tissue capsule which is very thick in some places and remarkably thin in others. These connective tissue fibers lie also between skin and implanted material. The skin is not fixed to the tampon. The latter shows different structures and colors. In some places it is hardly impaired and only infiltrated by serous fluid (*a*). In other places the typical fibrous structure of the material has disappeared (*b*); here are found caseous and crumbling masses in the midst of which are foci of leucocytes that are mostly necrotic (pyknosis, caryorrhexis, caryolysis, fattening, etc.). In many places the rests of the material, stained with eosin-hematein and varying in general from a light to a dark red color, are violet blue; especially the periphery of the fibers shows this discoloration as well as a somewhat crystalline structure which, according to the silver nitrate reaction, appeared to be chalk. Apart from the destruction of the tampon material at the site of the masses of leucocytes described above, there is observed in the greater part of the periphery of the tampon (*c*) an advanced fibrous organization and substitution of the implanted material. Here the fibers of the tampon material are broken up, ruptured, and surrounded by fresh connective tissue which gradually merges with the fibrils of the capsule. This process of organization is completed in some areas (*d*); *e* represents subcutaneous tissue, and *f* skin.

in gaps of this material similar to osteoclasts in the region of a fracture. The number and the activity of the leucocytes vary largely. Probably secondary factors, namely, tissue injury and necrosis of the surrounding tissue by the operation or by infection, play an important part. The collagen per se of the tampon material has no leucotropic action. Therefore, the tampon, as a rule, does not suppurate, unless infected cavities are tamponed or an abundant use is made of tincture of iodine in the wound. Then the process of organization is confined to the envelopment of the tampon that is totally destroyed by leucocytes. However, even these focal infections disturb the histologic appearance of the surrounding tissue astonishingly little. The resorption period of the tampon, i.e., the time in which the implanted material either dissolves or is made part of the organism by organization, depends on the size of the tampon, the vascularity of the surrounding area, and the quality of the tampon material. Generally large tampons remain longer than small ones and vascular tissues, such as the spleen or the liver, enhance absorption. The structure of the tampon surface is also important. The more porous the material, the more rapid is the process of organization. For these reasons it is not possible to determine definitely the time required for absorption. In some instances the fibers of the tampon material cannot be recognized six weeks after implantation; whereas, in others distinct rests of the spongy material may be observed even after six months.

In more than 100 experiments there was not a single case in which the tampon was extruded, even from an infected area. On the contrary, it seems that the presence of pus promotes the digestion of the tampon material. Instead of the tampon, there was found an encapsulated caseous area which, on microscopic examination, did not show any tampon fibers. It consisted solely of fatty leucocytes. When the reaction of the organism is neither disturbed nor interrupted, after a varying period of time there remains a connective tissue cicatrix that is much smaller than the original tampon. When a large tampon has been used, this end effect will be reached only after a year. Smaller tampons are organized much more quickly.

The minimal degree of irritation to the surrounding tissue is impressive. The simultaneous occurrence of the processes of organization and destruction of the implanted material is quite characteristic. This is demonstrated clearly in Figs. 1 to 8 (Rabbit 99) which were made by L. H. Bretschneider, histologist of the Zoological Laboratory of the State University at Utrecht. On June 1, 1938, a large tampon was placed into the subcutaneous fat through an incision in the skin of the abdominal wall of an experimental animal. The cavity had been treated previously with tincture of iodine. On Jan. 18, 1939, the tampon, together with the surrounding abdominal wall, was extirpated. The tampon could be palpated as a firmly elastic, subcutaneous mov-

able nodule of about one-half inch in diameter. It was placed in formalin, sectioned, and stained with hematoxylin-eosin. On microscopic examination the implanted material appeared encapsulated between the fascia and the subcutaneous tissue showing focal necrosis in the center with leucocytic infiltration, giving it the appearance of ground glass. In some parts the tampon was considerably absorbed; whereas, other areas revealed various stages of absorption and substitution by granulation tissue and connective tissue. A few rests of the tampon at the periphery mark the border of the implanted body.

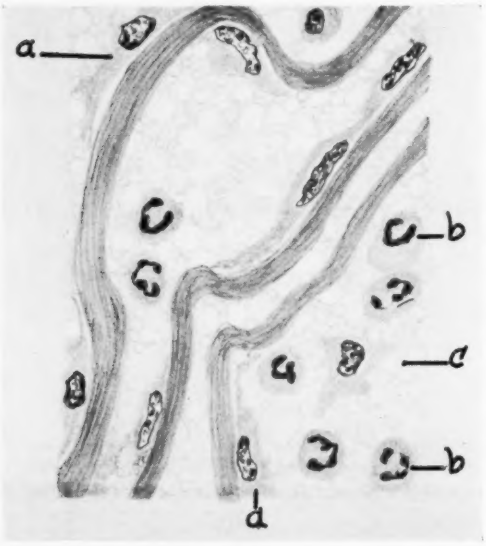

Fig. 3.

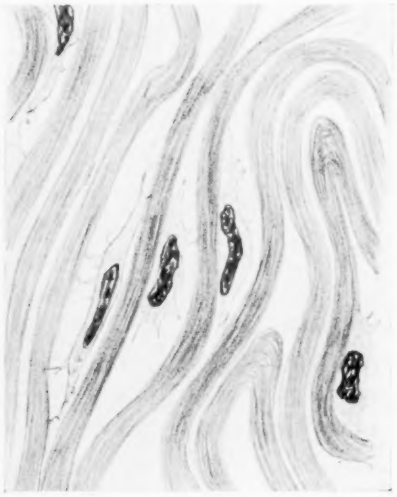

Fig. 4.

Fig. 3.—Drawing of microscopic section of tampon material showing serous exudation and infiltration of leucocytes and fibroblasts. The fibroblasts lie adjacent to the tampon material and the leucocytes in the serous exudate. *a*, Fibroblasts; *b*, leucocytes; *c*, serous exudate. (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 5.)

Fig. 4.—Drawing of microscopic appearance of section of tampon material, showing invasion of young connective tissue cells between unimpaired tampon fibers. (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 5.)

Thus, two absolutely different types of the absorption process are observed: (1) fibroblastic infiltration associated with invasion of giant cells whose absorption function is most apparent where they affect the tampon material (corrosion of the tampon fibers) (Figs. 5 and 6); (2) leucocytic infiltration with focal necrosis and destruction of the tampon material (Figs. 3 and 8).

In both cases the tampon is gradually replaced by granulation tissue (Figs. 5, 6, and 8). Gradually the oval connective tissue cells with collagen fibers and vascular endothelium become predominant. Young collagen connective tissue appears and the original boundary between the organized implanted body and the capsule is no longer perceptible.

It is a well-known fact that the subcutaneous fat tissue of the abdominal wall is poorly suited for absorption of an implanted body. Moreover, in this particular experiment the tissue was irritated by

tincture of iodine and there was the danger of secondary infection from the skin wound. However, in spite of this, the tampon was not extruded. It appeared that even the skin had not become adherent to the implanted body. In other tissues and in parenchymatous organs in which the reactions produced by the tampon are less liable to the disturbing action of exogenous factors (operative trauma, infection, wound healing), the processes of absorption and organization of

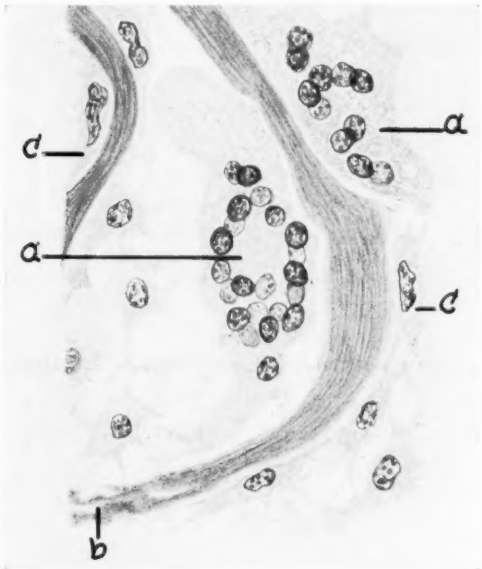

Fig. 5.—Drawing of microscopic appearance of histologic section of tampon material showing: *a*, phagocytic giant cells on tampon fibers; *b*, autolysis of tampon fibers by ferment action resulting in granular and frayed appearance of the fibers; *c*, fibroblasts. (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 10.)

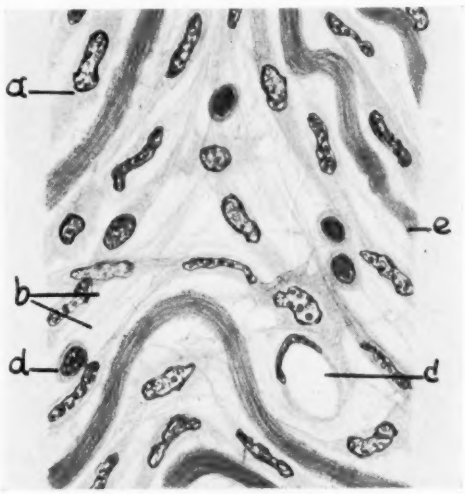

Fig. 6.—Histologic section of implanted tampon material showing beginning organization of the interfibrillar exudate: *a*, young fibroblasts; *b*, fibroblasts with collagen fibers; *c*, young capillary vessels; *d*, fat cells; *e*, partly granulated tampon fibers (beginning of destruction). (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 5.)

the incorporated material occur less equally. But in these cases, also, these two processes, namely the destruction of the implanted material and the secondary organization by granulation tissue and by primary connective tissue growth, as a result of fibroblastic invasion of the unimpaired fibers of the implanted body are almost always recognizable. This primary growth of connective tissue, in my opinion, is due to the affinity between the fibroblasts and the collagen substance that evidently can be used immediately by the young cells for the construction of new fibers. Apparently the same forces are operative in this case as in the rehabilitation of Nageotte's *greffes mortes*. Indeed, in some very compact parts of the implanted bodies that resist the penetration of serum longest, some adult oval cells are found quite isolated

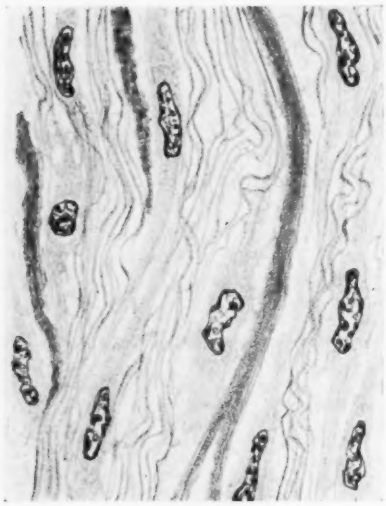

Fig. 7.

Fig. 8.

Fig. 7.—Histologic section of implanted tampon material, showing advanced connective tissue-like organization and destruction of the tampon fibers which lose their fibrous structure. (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 10.)

Fig. 8.—Histologic section of implanted tampon material at borders of the destructive center, shown by *b* in Fig. 3. *a*, Granular mass of tampon material (stained dark red in the preparation) with focal areas of leucocytes; *b*, necrobiotic leucocytes; *c*, beginning destruction and fragmentation of tampon fibers; *d*, unimpaired tampon fibers. (Enlarged oil-immersion Bausch and Lomb, 1.25. ocular 5.)

from the living tissue at the periphery, and in such close contact with the collagen fibers of the implanted body that it is clearly a question of a genuine rehabilitation. The structure of the tampon here appears to be readily habitable for connective tissue cells. As a rule this primary fibrous organization prevails in the deeply implanted and compact tampons that are least exposed to disturbances (Fig. 3) and that resist best the serocellular infiltration and consequent ferment and phagocytic actions of the leucocytes. In noncompressed tampons and in those lying in operative wounds the destructive processes be-

come more prominent and, in an infected tissue, may even culminate in the destruction of the material by pus and the encapsulation of the necrosis as described above.

CONCLUSIONS

The characteristics of a new, assimilable material that might be useful in surgery, namely, for tamponade and isolation of tissues and organs, were studied experimentally and the result described. The material, brocatamp,* consists of collagen and appears perfectly non-irritating to the surrounding tissues when implanted in rabbits.

It is partly absorbed by the lytic activity of ferments and by phagocytosis, and partly organized either by direct infiltration of connective tissue cells or by the formation of granulation tissue.

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*Brocatamp was kindly placed at my disposal by Messrs. N. V. Koninklijke Pharmaceutische Fabrieken v.h. Brocades-Stheeman and Pharmacia Meppel.

SOLITARY TRUE DIVERTICULUM OF THE CECUM

Report of a Case

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SOLITARY true diverticula of the cecum seem to be quite rare, since in a recent article Bennett-Jones[1] was able to collect only nineteen cases and added three, the treatment of which he had observed. However, he makes the statement, which is very likely true, that probably there have been a good many other cases that have not been reported because of poor or fatal results or else that they have been reported in obscure journals. We wish to add one more case to those already reported.

Mrs. E. P., white woman, aged 42 years, had been under treatment by one of us (Dr. Z. Morgan) since September, 1933, for a mild thyroid and pituitary deficiency. During this period she had had occasional attacks of abdominal pain localized to the right lower quadrant which were suggestive of recurrent appendicitis. Her past and family histories were relatively unimportant, except that she had developed an incisional hernia following a cesarean section in 1935. This hernia was becoming larger and commencing to give her trouble. She had had typhoid fever at 18 years of age, a tonsillectomy and an appendectomy in 1925, and a benign tumor removed from the right breast in 1934.

She was admitted to the Church Home Hospital on April 7, 1939, after having suffered with severe abdominal pain for the previous four days. The pain, which at first seemed to be generalized over the whole abdomen, had been associated with nausea and fullness. By the time she was admitted, the symptoms had become localized to the right side. She had not vomited, and bowel movements had been normal.

Examination on admission showed her temperature to be 98.6° F., pulse 84, respirations 20, blood pressure 140/80, hemoglobin 72 per cent and white blood count 12,250. She was in no particular pain at the time of examination, complaining only of soreness in the right side. Examination of the abdomen revealed marked tenderness with reflex muscle spasm at McBurney's point. There was an old midline scar with a fairly marked hernial defect at its upper angle. Otherwise the examination was essentially negative. A diagnosis of subsiding appendicitis and incisional hernia was made. Operation was advised, and the patient consented.

The abdomen was explored through the old incision, with the idea of repairing the hernia at the same time the appendix was removed. Gas-ether anesthesia was used. Upon opening the peritoneum, a large hard mass with a crater in its center was felt in the lateral wall of the cecum directly opposite the ileocecal valve, and there were some hard glands present in the mesentery. There was no evidence of any obstruction. The cecum was exposed, and even under direct vision it was impossible to tell whether we were dealing with an inflammatory process or a new growth. In view of this uncertainty, it was thought best to do a wide resection, so the right side of the colon, including the cecum and terminal ileum, was removed in a single block. The cut end of the transverse colon was inverted, and an aseptic

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end-to-side anastomosis was performed between the ileum and transverse colon with Stone's clamps. The hernia at the upper angle of the incision was repaired in the usual manner. The patient had a very uneventful postoperative course.

The pathologic report on the specimen (Dr. V. H. Norwood) was: "Diverticulum of the cecum (true), showing acute inflammation with ulceration and a large fecalith. Appendicitis acute secondary."

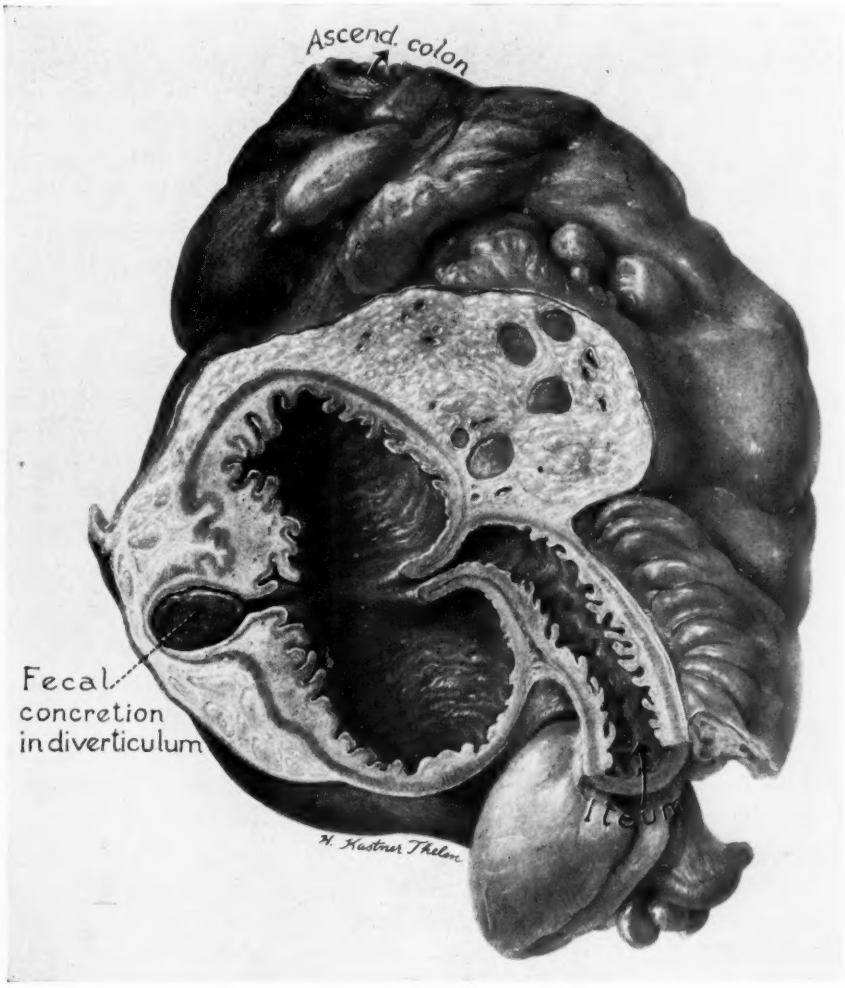

Fig. 1.

On April 20, thirteen days following the original operation, the patient, while bathing, noticed a small lump in the right breast, which she called to our attention. Upon examination the lump was found to be about the size of a small hazelnut. It was freely movable, being deeply buried in a rather large fatty breast and apparently not attached either to the skin or underlying tissue. Since the patient was very fearful of carcinoma of the breast, she was advised to have the lump removed more for her mental satisfaction than any other reason. The nodule was removed under local anesthesia on April 25, and, much to our surprise, the routine frozen section showed medullary carcinoma. The next day a simple mastectomy was done, with the removal of the lower axillary glands and the fascia over the pectoral

muscles. A radical operation was not done because of the very small size of the growth. Again she had a quite uneventful postoperative course and was discharged from the hospital on May 7. Following discharge she was given a full course of radiation. She has had no evidence of recurrence to date and no symptoms referable to the partial resection of the colon. On July 7 she was carefully fluoroscoped, and x-rays of a barium enema were made in an attempt to discover diverticula elsewhere in the colon. The report of this examination is as follows (Dr. Pierson): "Cecum and ascending colon have been resected. The anastomosis is working perfectly. No diverticula demonstrated."

This case follows very closely the pattern shown by previously reported cases, in that the usual preoperative diagnosis was acute appendicitis and that, when a large mass was found on the wall of the cecum, it was impossible to tell whether it was malignant or not, so a wide resection was done to play safe. The end result was also in accord, since to date only one death has been recorded in this type of case. In a good many cases there was only a very small diverticulum which was treated by local excision and closure of the neck. There were nine cases in which the mass was large enough to make the diagnosis doubtful and which, therefore, required resection. The one death occurred in this group. Obviously, local excision is the procedure of choice if the size of the lesion permits. The only unusual feature about our case was that the patient, while bathing during the postoperative course from her first operation, accidentally discovered a small nodule in her breast. This nodule was a carcinoma and required removal of the breast.

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CONGENITAL HOURGLASS BLADDER

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THE condition known as congenital hourglass bladder can be considered one of the rarer anomalies, with a total of sixteen cases now in the literature. It may be defined as a congenital anomaly in which the bladder is divided into two smaller cavities by a transverse constriction, without definite change in total volume and without change in the component parts of the bladder wall except at the constriction where the bladder is twice the normal thickness. The constriction may occur either above or below the ureteral orifices. Congenital hour-glass bladder must be distinguished from hourglass deformities of the bladder due to other causes such as (1) diverticulum, (2) patent urachus, (3) vesica duplex or vesica bipartita, (4) absence of the prostate and seminal vesicles, either congenital or surgical, and (5) constriction due to inflammatory conditions such as tuberculosis or severe cystitis, or as a result of extrinsic or intrinsic injury.

ETIOLOGY

The condition of congenital hourglass bladder must have some reasonable embryologic basis for its occurrence, and various theories have been proposed. These theories have been well summarized by Eisenstaedt and McDougall,[1] who have divided them into three groups as follows:

1. Atavistic relationship or hourglass bladder normally found in some animals.
2. Persistence of the embryonic ureteric membrane.
3. Unequal growth of the two bladder anlagen.

The atavistic relationship to the hourglass bladder found in lower animals was suggested by Krasa and Paschkis[2] who found many types of hourglass bladder in a variety of animals. The persistence of the embryonic membrane of the ureter as the etiological factor was suggested by Chwalla[3] as a result of studies of Hochstetter's embryos in which he found such a membrane in a 37 mm. embryo. Ordinarily this membrane disappears before the 28 mm. stage. The theory of unequal growth of bladder anlagen was first stated by Pagenstecher,[4] and later by Gruber[5] who believed that there is a failure of perfect union of the trigonal portion which is of mesodermal origin and the bladder proper which is of endodermal origin. In regard to the latter theory, we must remember that it is only the lining of the bladder which is endodermal. The bladder musculature is mesoderm and is, therefore, of the same material as the trigone. At the present time we believe that the evidence for or against either of these theories is insufficient upon which to draw a reasonable conclusion.

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TABLE I

AUTHOR AND YEAR	AGE	SEX	LOCATION OF URETERS	RELATIVE SIZE OF CAVITIES	SIZE OF OPENING	SYMPTOMS	TREATMENT	REMARKS
Passo, 1848[6]			Lower					
Cutter, 1854[9]	11	M	Not stated	Not stated	Small	Dysuria for one year. Blood and pus in urine	Expectant	Spontaneous rupture of abscess in right inguinal region. Death from bilateral pyonephrosis
Fothergill, 1878[10]			Lower					
Detwiler, E. L., 1888[7]	69	M	Upper	Compartments about equal. Diverticulum of upper cavity size of walnut, which abscessed into groin	Admitted point of index finger	Dysuria 3 to 4 years, with incontinence. Dyspepsia and debility	Incision and drainage of abscess in groin and scrotum. Urethral dilatation	Urethral stricture. Death. Autopsy showed left pyonephrosis and pyoureter
Muller, 1895[11]		F	Lower					
Fuller, E., 1900[12]	55	M	Upper	Not stated	Two fingers; oval	Gradual increasing difficulty since childhood, hematuria 2 to 3 weeks	1. Perineal section 2. Suprapubic cystotomy with incision of band with scissors.	Urethral stricture (postgonorrheal). Patient recovered.
Fuller, E., 1900[12]	44	M	Upper	Capacity lower cavity 1 to 1½ oz. Upper cavity twice size of lower cavity. Both lined with transitional stratified epithelium	Barely one finger; circular	Gradual increasing difficulty since childhood	1. Perineal section 2. Suprapubic cystotomy with incision of band with scissors.	Urethral stricture (postgonorrheal). Small stone. Died 10 days postoperative from uremia. Autopsy
Pieleke, O., 1904[13]	34	M	Lower	Upper cavity size of an apple. Size of lower cavity not stated	Three marks coin; oval	Obstipation with intermittent diarrhea. Palpable tumor. No urinary symptoms	Not stated	Bladder projected above symphysis

Pieleke, O., 1904[13]									No data by author
Fischer, H., 1910[14]	75	M	Lower	Upper cavity twice size of lower	Size of quarter	Difficulty all his life. Nocturia and hematuria for 10 years; stoppage for 10 years. Used catheter	Cystotomy; diverticulum; drained by Witzel tube	Recovered from operation. Died 1 year later from uremia
Caulk, J. R., 1920[15]	42	M	Lower	Upper larger than lower	Not stated	Enuresis until 9 years of age. Dysuria for 9 years. Acute retention.	Suprapubic cystotomy, with resection of base of bladder	Recovered
Caulk, J. R., 1920[15]	42	F	Lower	Bladder contracted. Capacity 150 c.c.	Not stated	Intermittent dysuria for 11 years	Suprapubic cystotomy, with resection of base of bladder	Reflux up right ureter. Recovered
Kretschmer, H. L., 1923[8]	83	M	Lower	Lower cavity slightly larger than upper cavity	Not stated	Dysuria for 12 years	Suprapubic cystotomy	Died 8 days postoperative. Autopsy
Kearns, W. M., and Turkeltaub, S. M., 1933[16]	22	F	Lower	Lower segment larger than upper (by cystogram)	2 cm.	Difficulty since early childhood. Hematuria	Upper cavity resected. Tightening of ureteral orifice. Nephrectomy	Hydroureter and hydronephrosis due to reflux. Recovered
Eisenstaedt, J. S., and McDougall, T. G., 1936[1]	42	M	Lower	Equal in size (by cystogram)	Three fingers	Enuresis until 14 years of age. Dysuria since	Entire muscle band excised	Diverticulum from upper cavity. Recovered
Ockerblad, N. F., and Carlson, H. E., 1940	63	M	Lower	Equal in size	2 cm.	Nocturia 5 to 6 years; difficulty 3 years, with increasing incontinence and hematuria. Self catheterization for 6 months	1. Suprapubic cystotomy and excision of muscle band 2. Transurethral resection of prostate	Recovered. Well five years later

INCIDENCE

It is a little difficult to separate in the literature the congenital hourglass bladder from the hourglass deformities of other etiology, since a certain degree of confusion exists. However, we have succeeded in collecting sixteen such cases, including a case of our own, which are summarized in Table I.

The first description fulfilling the requirements of a congenital hourglass bladder was by Passo in 1848. An exact description of the autopsy findings is given which leaves no doubt as to the condition found.[6] The first use of the term hourglass bladder in relation to the congenital type was by Detwiler in 1888.[7] It is probable, however, that the name had previously been used in describing bladders with diverticula.

The condition to date has been more frequent in men than in women. Of the sixteen cases, ten were in males and three in females, and in three the sex was not stated. The age was extremely variable. The youngest patient was 11 years old, as described by Cutter,[8] and the oldest was 83, as described by Kretschmer and Morris.[9] The average age of twelve cases was 48.5 years.

DIAGNOSIS

The symptoms of congenital hourglass bladder were quite variable, but, as might be expected, 66 per cent of all persons complained of lifelong bladder disturbance. The early symptoms include urinary difficulty, dysuria, or a history of enuresis. The symptoms of urinary difficulty and dysuria continue into later life and eventually bring the patient to the doctor. Thirty-three per cent, however, had no symptoms until later in life. Two patients had acute urinary retention, and one had hematuria. It has been suggested that it is the superimposing of a cystitis on the congenital deformity that produces most of the disturbance. The patient presented by us had a severe cystitis with an extremely purulent urine.

On cystoscopic examination, the bladder is found to be divided into two cavities, one above the other, which are connected by an opening from one to three fingers in width. The ureters may open either into the lower or the upper compartment. The relative size of the two compartments is variable, but the combined capacity of the two compartments is that of a normal bladder. The margin of the opening is seen to be thick, is generally twice the thickness of the bladder wall, and does not present the shelflike edge seen in the opening to a diverticulum. When the cystoscope is introduced into the upper cavity, normal trabeculations and normal vessel markings are seen. We, therefore, have two distinct cystoscopic features to differentiate congenital hourglass bladder from an hourglass deformity due to a diverticulum. Congenital hourglass bladder can be differentiated from hourglass deformity due to a persistent urachus since the contours of the hourglass bladder are rounded and it does not have the spiked upward extension seen with a patent urachus. If there is any doubt, a cystogram will assist in the

identification of these two conditions. The differentiation of a congenital hourglass bladder from a congenital absence or surgical absence of the prostate and seminal vesicles should not be difficult. An hourglass constriction of the bladder due to inflammation, such as chronic cystitis or tuberculosis, or to either extrinsic or intrinsic injury is conceivable, but that it would ever approach a condition closely resembling that of a congenital hourglass bladder is extremely unlikely. Certainly, however, an hourglass type of bladder with a large communication may be regarded with suspicion.

TREATMENT

The treatment of congenital hourglass bladder should be directed toward enlargement of the opening between the two halves of the hourglass so as to allow better drainage and more complete emptying of the bladder. Since the total capacity in these cases closely approaches that of the normal bladder, it seems more plausible to follow some procedure concerned with the eradication of the fibrous ring rather than to remove the upper portion of the hourglass as would generally be done with a diverticulum. Where the ureters empty into the upper half, there is, of course, no choice in the matter. Of the sixteen patients, nine were operated upon. Two had suprapubic cystotomy only. In six, some type of operation directed at removal of the fibrous ring was done, and in one in whom the upper cavity was small, a resection was done. Of the six cases in which the fibrous ring was removed, the base of the bladder was resected in two; in two cases the ring was cut with a scissors; and in two the entire muscle band was excised. Of the nine patients who underwent operation, six recovered and three died.

CASE REPORT

W. H. M., No. L-50673, white male, a physician, aged 63 years, was admitted to the hospital on April 14, 1934. He complained that for the past five or six years he had had an increasing nocturnal frequency and that for the past three years he had had increasing difficulty of urination, with a developing urgency and increasing incontinence with some hematuria. For the past six months he had been catheterizing himself daily, with the exception of the past month when he used the catheter every eight hours.

Examination showed the presence of an ankylosing osteoarthritis of the spine, sacroiliac joints, and one hip joint. Rectal examination suggested an enlarged prostate.

Laboratory examination showed the urine to be alkaline, with a specific gravity of 1.013, albumin 4 plus, no sugar, and with 20,200 pus cells per cubic millimeter and 3,200 red blood cells per cubic millimeter on microscopic examination. The blood showed a red blood cell count of 3,920,000, a white blood cell count of 9,000, and hemoglobin, 78 per cent. The Wassermann and Kahn tests were negative. The intravenous phenolsulphonphthalein test showed a total output of 27 per cent in one hour.

Cystoscopic examination showed a small median bar with a bladder of evidently greatly diminished size. The bladder was full of debris, and the mucosa showed the presence of a rather severe chronic cystitis. There was an opening about 2 cm. in diameter in what appeared to be the dome of the bladder. An air cystogram was then taken which revealed the presence of an hourglass deformity (Fig. 1).

Treatment.—Because of the severe infection in the bladder, a suprapubic cystotomy was done. The upper cavity was first entered. The cavities appeared about equal in size. Examination showed that the fibrous ring was extremely tough and very thick and was at least twice the thickness of the bladder wall. The opening was about 2 cm. in diameter. The walls of both cavities were found to be of equal thickness and presented similar layers and appearance. Considerable cystitis was found. Examination of the lower cavity showed that the ureters opened into it in normal position and that there was a small pedunculated prostate present. The neck of the hourglass deformity was dissected out, making one large cavity out of the two. The incision was closed with drainage.

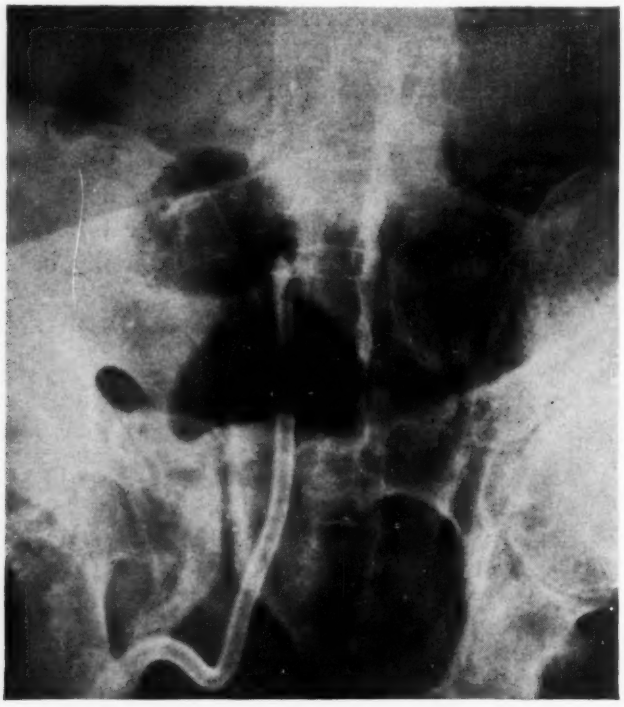

Fig. 1.—Air cystogram showing hourglass appearance of the bladder.

Twelve days later when the cystitis had subsided five large pieces of fibrous prostatic ring were resected with the McCarthy resectoscope. The suprapubic incision promptly healed, and the patient was dismissed from the hospital one week later.

Five years after the operation the patient reported that he had had no bladder trouble and that he was still practicing medicine.

SUMMARY

1. Congenital hourglass bladder is one of the rarer human anomalies, with a total of sixteen cases, including a case of our own, now recorded in the literature.

2. The exact etiological factor responsible in the embryo for the constriction which divides the bladder into two cavities like an hourglass is not known, but it may be due to one of the following, namely, an atavistic relationship to hourglass bladder normally found in some animals, the persistence of the ureteric membrane, or unequal growth of the two bladder anlagen.

3. The condition is most common in males, in a ratio of ten to three. The youngest patient was 11 years of age, and the oldest 83 years of age, with an average age of 48.5 years.

4. Sixty-six per cent of the patients evidently had had some urinary disturbance since early life, including urinary difficulty, dysuria, or enuresis. Thirty-three per cent had no symptoms until later in life. It is probable that the development of a severe cystitis in a patient with an hourglass deformity is responsible for most of the symptoms.

5. The diagnosis is made by cystoscopy. The most distinguishing cystoscopic characteristics are the thick margin of the opening between the two cavities, the occurrence of normal bladder markings in the upper as well as the lower cavity, and a total bladder volume that is apparently unchanged from the normal. The ureters may open either above or below the constriction. Cystoscopically, the condition must be distinguished from other hourglass deformities, mainly from those due to diverticula. The diagnosis is substantiated at operation where the two cavities are seen to have walls of equal thickness which are normally constituted, and a constriction ring which is generally twice the thickness of the bladder wall.

6. Since the total bladder volume is apparently unchanged from that of a normal bladder, it is generally best to follow some procedure concerned with the eradication of the fibrous ring, whether the ureters open into the upper or into the lower cavity.

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THE VIABILITY OF THE TESTIS FOLLOWING COMPLETE SEVERANCE OF THE SPERMATIC CORD

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OWING to a recent opportunity to examine microscopically a testis whose spermatic cord had been severed, we are no longer in doubt concerning our observations on viability of the testis after deliberately performed section of the structures of the cord. Until this opportunity had been vouchsafed, we hesitated to report clinical observations which had been made over a period of years and whose presentation is the main purpose of this paper. In addition, the literature on the subject will be reviewed, the blood supply and collateral circulation of the testis will be discussed, experimental observations of others will be analyzed, and an explanation will be offered for the variation in results after complete severance of the cord.

Despite its clinical importance, there is no unanimity of view as to the effect of complete severance of the structures of the cord on the testis. Although the literature on the subject is scanty, it appears to have been generally assumed and accepted that the results range from partial or complete atrophy to gangrene. For example, Lower[1] states that, following the division of the entire cord in direct inguinal hernioplasty, "in all cases there has been very marked atrophy after a period of time." Eisendrath and Rolnick[2] observed that "ligation or division of the entire spermatic cord results in complete atrophy of the testicle and very often gangrene." On the other hand, Burdick and Higenbotham,[3] in a report on severance of the cord in a large number of hernioplasties, observed that "many of the testicles atrophied but it was surprising how many did not." Although a statistical analysis of the results in their cases was not made, at least the fact that atrophy did not occur uniformly should be stressed as an experience at variance with a generally or widely held view.

In contrast to the scanty clinical contributions to the subject, considerable anatomical and experimental literature is available. The data which this literature contains will now be presented.

ANATOMICAL CONSIDERATIONS

According to Luschka (1863),[4] the spermatic artery carries the sole blood supply of the testis. He recognized the existence of an epididymal branch but did not speak of its anastomosis with the deferential artery. Sappey (1873)[5] was the first to recognize such an anastomosis. Later,

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Henle (1878)[6] and Pastau and Testut[7] described again the anastomosis between the deferential and spermatic vessels. Jarisch (1888)[8] showed that the testis received its arterial supply from three sources: the internal spermatic (the main supply), the deferential, and the external spermatic arteries. He did not recognize any relationship of these vessels with the scrotal system. Capurro (1901)[9] studied the arterial anastomoses of the testis in the dog by injecting gelatin into the internal spermatic artery through the aorta. Colle (1902)[10] confirmed the rich anastomosis and in addition showed that the scrotal vessels of both sides communicated across the midline and anastomosed with the external spermatic branches. Picqué and Worms (1909)[11] injected the internal spermatic artery at its entrance into the spermatic cord, verified the foregoing observations, but were unable to find any communication between the scrotal and testicular vessels. The cremasteric artery was sometimes found inside the cord structures and at other times outside. Under the latter circumstances it gradually found its way by oblique penetration of the various coats of the cord until it reached the inferior portion of the testis to anastomose with the deferential and epididymal branch of the spermatic artery. Several types of anastomosis were described by Picqué and Worms (Figs. 1, 2, and 3).

According to Piersol,[12] "the front and sides of the scrotum are supplied by the anterior scrotal branches from the deep and superficial external pudic arteries and the back and septum are supplied by the posterior scrotal artery, a branch of the internal pudic. Free communication exists not only between the vessels of both sides across the midline but also between the anterior and posterior branches at the sides. The scrotal arteries anastomose with twigs from the obturator and internal circumflex as well as from the cremasteric artery."

The evidence points to the cremasteric artery as the key vessel in the collateral circulation when all the vessels in the cord are tied off above the scrotum, since it alone communicates with the scrotal system on the one hand and the testicular system on the other (Fig. 4).

The venous circulations of the testis and epididymis were studied carefully by Haberer[13] in 1898. He showed that the blood returns by four possible routes: (a) Blood from the testis, into the anterior and posterior portions of the pampiniform plexus; (b) upper two-thirds of the epididymis, to the anterior pampiniform plexus through the epididymal veins; (c) tail of epididymis, by the deferential vein into the venous plexus about the seminal vesicles; (d) coverings of testis and cord, by the external spermatic vein into the inferior epigastric vein.

Anastomoses between the veins occur only in the lower portion. According to Wangensteen,[14] interruption of the veins in the pampiniform plexus below the anastomoses will interfere with the circulation in the testis more than ligation of the internal spermatic vein high in the extraperitoneal region.

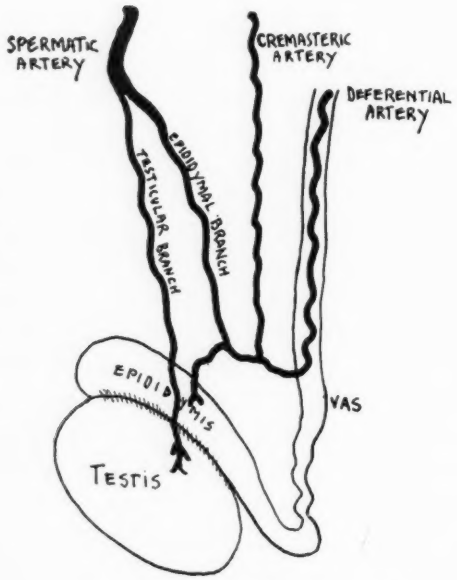

Fig. 1.—Showing anastomosis between the epididymal branch of the spermatic artery with the cremasteric and deferential arteries. (After Picqué and Worms.)

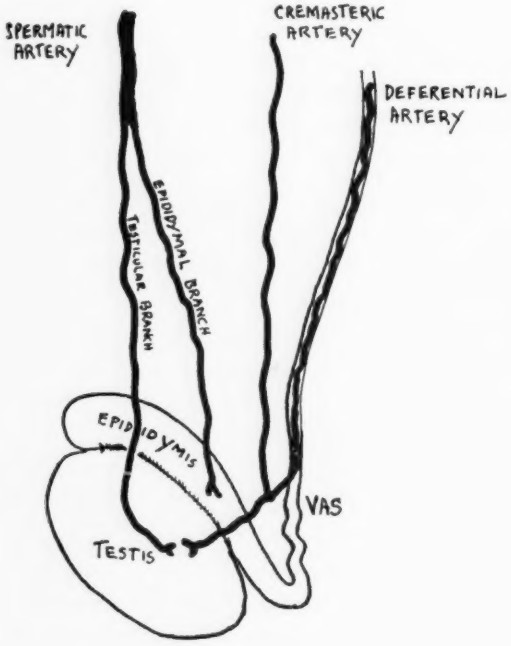

Fig. 2.

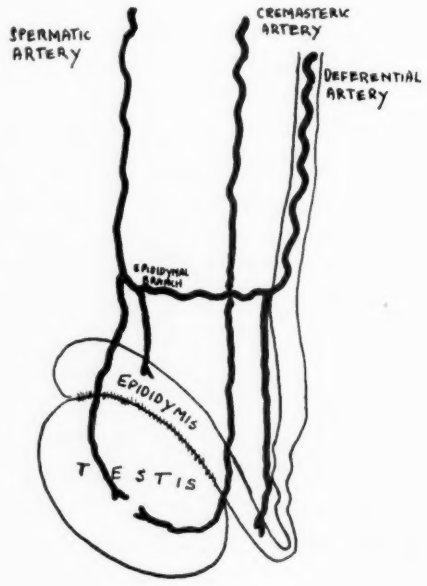

Fig. 3.

Fig. 2.—Showing anastomosis between the testicular branch of the spermatic artery and a branch from the cremasteric-deferential system. (After Picqué and Worms.)

Fig. 3.—Showing double anastomosis (1) between the testicular branch of the spermatic artery and the cremasteric artery; (2) between the epididymal branch of the spermatic artery and the deferential artery. (After Picqué and Worms.)

EXPERIMENTAL AND CLINICAL OBSERVATIONS

The blood supply of the testis and epididymis in dogs was found to be similar to that in man by a number of investigators (Ludwig and Tomsa,[15] Griffiths,[16] Ellenberger and Baum,[17] Wangensteen[14]). Practically all of the experimental work on this subject was done on dogs; the results have been interpreted as being applicable to man.

Cooper (1845)[18] was the first to study the effect of ligation of the vessels of the spermatic cord. On one occasion he divided between ligatures the whole of the spermatic cord. Sloughing and gangrene of the testis took place and he was content apparently with the result of this single experiment. Miflet (1879)[19] showed that obliteration of the internal spermatic artery in dogs was followed by hemorrhagic infarction of the testis and that ligation of the internal spermatic veins alone

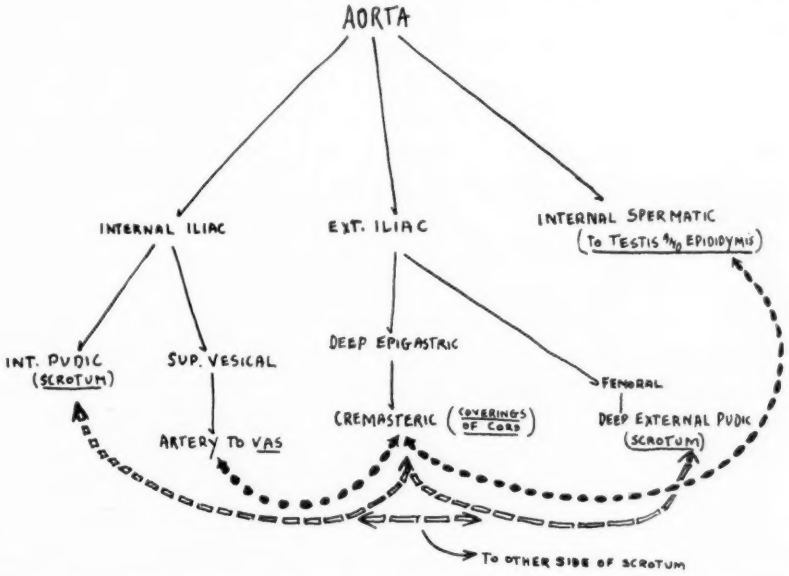

Fig. 4.—Schematic outline showing the cremasteric artery to be the key vessel between the testiculocremasteric-deferential-arterial system on the one hand and the scrotal-arterial system on the other.

was sufficient to cause degeneration of the testicular parenchyma. Thus, hemorrhagic infarction of the body of the testis followed by atrophy of the gland resulted whether the artery or the vein was ligated. However, Kocher (1887),[20] Treves (1891),[21] and Bennett (1893)[22] found that obliteration of the internal spermatic artery and veins caused neither sloughing nor atrophy. While changes may be produced in dogs by interference with the blood supply, long sections of pampiniform plexus with the spermatic artery may be removed for varicocele in man with impunity. Griffiths (1895),[16] as a result of experiments on dogs, reverted to the older view. He observed that "1. Ligation of the spermatic artery in full grown dogs leads within a few days to great diminution in the bulk of the testis, caused by rapid destruction from degenera-

tive changes in the seminal tubules; but, after a time the remaining tubules may recover to such a degree as to be capable again of producing spermatozoa in the usual way. 2. Ligation of all the spermatic veins leads to great swelling from engorgement of the veins and extravasation of blood into the intertubular connective tissues, and to necrosis of the epithelial cells in the seminal tubules. This condition would ultimately cause almost complete disappearance of the seminal tubules and atrophy of the gland. 3. Ligation of the spermatic artery and veins in puppies leads to great swelling of the testis and atrophy of the organs. 4. Ligation of the spermatic artery and veins in full grown dogs may lead to sloughing of the testis, complete atrophy and temporary fatty degeneration of spermatogenic cells in the seminal tubules which may be followed by complete recovery."

In 1902 Mignon[23] advocated section of all the vessels in the spermatic cord with the exception of those accompanying the vas deferens, as a measure to aid in the placement of the maldescended testis in the scrotum. Bevan (1903)[24] concluded independently from operations on varicocele, in which he had sacrificed all the vessels of the spermatic cord except those accompanying the vas, and in which no apparent interference with the testicular nutrition had occurred, that these vessels "could be safely sacrificed in those cases where it was necessary to divide them in order to bring the testicle well down in the scrotum." Moschcowitz (1910)[25] divided the spermatic vessels in dogs and removed the testis at periods varying from four days to three weeks after operation. In no instance did gangrene occur. Microscopically, some necrosis in the interior of the testis was noted occasionally, but the alveoli showed some degree of preservation in the periphery. Gessner,[26] operating according to Bevan on dogs (that is, division of all structures of the cord, except the vas, its artery and veins), found testicular atrophy in four out of five dogs, and therefore argues against avoidable division of the vessels of the cord. However, the section apparently was made in the scrotum. Mixter (1924)[27] found it necessary to divide the internal spermatic vessels in 15 out of 107 cases of undescended testes. Atrophy followed in all but 2 of these cases. Wangensteen (1927)[14] showed that "section of the internal spermatic artery is followed always by diminution in the size of the dog's testis and by scattered degenerative changes in the tubules; spermatogenesis, however, still continues. Ligation of the internal spermatic artery with either the anterior or the posterior group of veins of the pampiniform plexus is followed by the same change that accompanies ligation of the artery alone. Ligation of the spermatic artery and all the veins in the pampiniform plexus always results in the total destruction of the testis."

It has been observed (Miflet, Wangensteen, and Joranson) that, while the testis atrophied, the epididymis remained normal. In seeking an explanation for this occurrence, Joranson (1928),[28] by perfusion ex-

periments in dogs, noted that the tunica of the testis was thicker and more unyielding than that covering the epididymis and that tension in the testis was greater than that in the epididymis. Comparable pressure disturbances might take place in the testis after ligation of the vessels. He suggested that incisions through the tunica albuginea or a bisection of the testis with orchidorrhaphy might prevent atrophy. Incidentally, he confirmed, in a general way, the three types of anastomoses described by Picqué and Worms and demonstrated anew that the spermatic system communicated with the scrotal vessels and that the latter were noted to communicate with each other across the raphe.

Ligation or Division of the Vas Deferens.—The procedure of vasectomy dates from 1845 when Cooper reported unilateral vasectomy in a dog. Six years later an examination showed that the epididymis was distended with spermatozoa. Gosselin[29] performed vasectomy in two dogs. He found the testes normal six and ten months later. Curling (1866)[30] reported four experiments of vasoligation in which sperm was found abundantly present after two to eight months.

Concerning changes in the testis, Spangaro[31] in 1903 was able to demonstrate spermatozoa in the testes but seemed surprised that no degeneration of testicular substance had been produced. Gregg[32] found the testes perfectly normal four years after accidental vasoligation at an operation for hernia. Wallace[33] concluded from experiments on dogs that there is some distention of the epididymis following vasoligation and no dilatation of the tubules and that the growth of the testis and its function of producing spermatozoa are independent of the integrity of the vas. Oslund,[34] experimenting on dogs, concluded that vasectomy does not cause degeneration of germinal epithelium of the testis, and Moore and Oslund[35] concluded from their experiments on sheep that vasoligation does not result in degeneration of the epithelium of the seminiferous tubules. Wangensteen, experimenting with dogs, found no significant change in the testis after vas ligation. The conclusions seem to be uniform, therefore, that no injury to the testis or epididymis follows vas ligation or vasectomy.

CLINICAL EXPERIENCES WITH SEVERANCE OF THE SPERMATIC CORD

It is to be emphasized that most of the experimental work on dogs was confined to ligature or division of only some of the structures of the spermatic cord. We are concerned in this paper with the results of complete cord severance. The literature on this subject is scanty. Despite disagreement as to the effect on the testis of experimental ligation of part of its blood supply, the clinical observations after ligation or division of the entire spermatic cord in man seem to us to serve as fair indicators of the fate of the testis and the epididymis.

The procedure of complete severance of the cord structures has been employed by us to achieve complete hernioplastic closure in selected

cases. However, there was one case (Case 10), in which severance of the entire cord was performed because a fibrosarcomatous tumor of the abdominal wall had involved the cord structures. There were 25 cases in which severance of the cord was employed. It was performed on one side only in all cases. There was no mortality. Eliminating 5 cases lost to follow-up or inadequately followed and 1 case in which orchidectomy was performed soon after operation (Case 13), there remain 19 cases for consideration. The follow-up varied from eight to fifty-five

Fig. 5.—The resected testis, epididymis, and spermatic cord.

months in these 19 cases. In 6 cases there was obvious atrophy of the testis (32 per cent); in 2 cases there was slight atrophy (10 per cent); and in the remaining 11 cases the testis, according to clinical observation of size and consistency, remained normal (57 per cent). There were, therefore, 13 cases in which little or no atrophy occurred (68 per cent). One case (A. H.) referred to above required orchidectomy soon after operation because of a dissecting hematoma which was due to an error in technique and is not ascribable to the severance of the cord.

In view of the fact that cord severance was performed only in those instances of hernioplasty in which recurrence was anticipated without complete closure of the canal, the incidence of 2 recurrences among 19 followed cases should be mentioned.

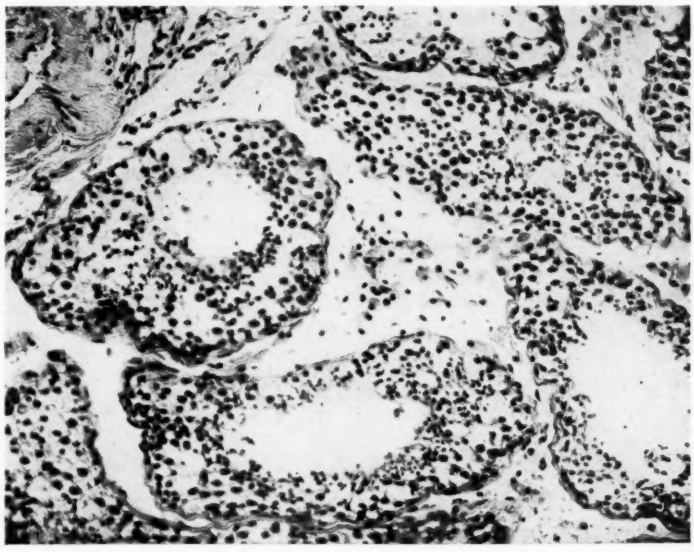

Fig. 6.—Low-power magnification of a portion of the resected testis (for description see text).

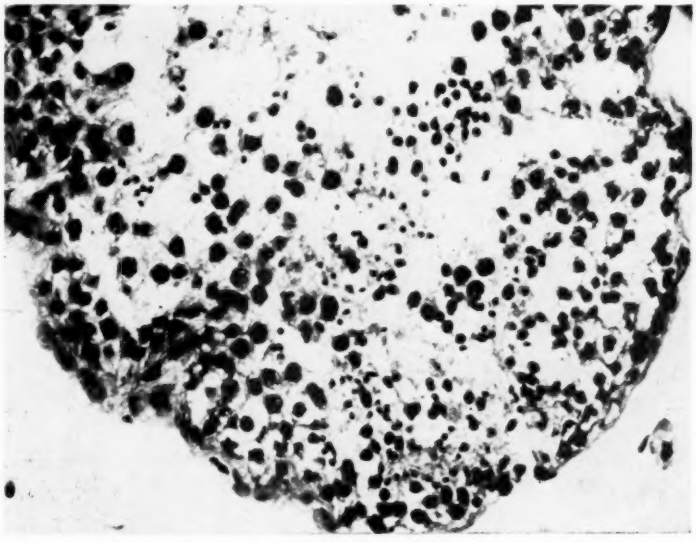

Fig. 7.—High-power magnification of a seminiferous tubule of the resected testis (for description see text).

Thus, in the study of this series of cases it is evident that retention of form and consistency of the testis occurred in the majority of cases so far as clinical observation was concerned. A recent opportunity to make a microscopic study of the testis in a case in which the structures of the

TABLE I

CASE NUMBER	NAME	AGE	HISTORY	DIAGNOSIS	OPERATION	FATE OF TESTIS	RECURRENCE OF HERNIA	PERIOD OF FOLLOW-UP
1	S. K. (No. 366333)	43	Left hernia 2 yr. duration	Left direct hernia	Hernioplasty and division of left cord (5/17/34)	One-half atrophy	No	13 mo.
2	N. T. (No. 394054)	33	Swelling in left inguinal region 1 wk.	Right recurrent inguinal hernia	Hernioplasty; right cord divided (6/36)	Atrophy	No	11 mo.
3	J. B. (No. 393461)	45	Lump in right groin 15 yr. duration	Right direct and indirect scrotal hernia	Hernioplasty; right cord divided (6/36)	O. K.	No	25 mo.
4	S. C. (No. 397880)	45	Hernioplasty 1 yr. ago; recurrence soon after operation	Right recurrent inguinal hernia	Hernioplasty; right cord divided (9/36)	Little smaller in size	No	8 mo.
5	H. G. (No. 383921)	50	Swellings in both inguinal regions for several years	Bilateral hernia	Bilateral hernioplasty; left cord divided (8/29/35); reaction right cord and testis postoperatively	Left O. K.	?	
6	J. L. (No. 396080)	45	8 yr. ago right inguinal hernioplasty; recurrence in 6 mo.	Irreducible right recurrent inguinal hernia	Hernioplasty; division of right cord (7/36)	O. K.	No	26 mo.
7	A. S. (No. 377304)	57	Right inguinal hernioplasty 7 yr. ago; recurrent in 2 yr.	Right recurrent irreducible direct-indirect inguinoscrotal hernia	Hernioplasty; right cord divided (3/5/35)	O. K.; right testis larger	No	55 mo.
8	H. C. (No. 393801)	20	Right hernioplasty 3 yr. ago; recurrence in 7 mo.	Recurrent inguinal hernia	Hernioplasty; right cord divided (5/29/36)	O. K.	No	31 mo. later, orchidectomy for suspected neoplasm; microscopic examination showed essentially normal testis

9	G. L. (No. 386966)	52	2 yr. ago left hernioplasty; recurrence in 3 mo.	Direct-indirect left hernia	Hernioplasty; division of left cord (11/35)	O. K.	?	12 mo.
10	A. C. (No. 362630)	42	6 mo. mass in right inguinal region	Fibrosarcoma of abdominal wall	Removal of tumor and division of right cord (2/13/34)	Right two-thirds size of left	No	36 mo.
11	P. R.	38	4/35, left hernioplasty; recurrence in 3 mo.	Left recurrent inguinal hernia	Hernioplasty and division of left cord (7/35)	One-third size of right	No	19 mo.
12	S. S. (No. 374034)	51	Bilateral inguinal hernia; small left sac, large right sac	Bilateral inguinal hernia	Bilateral inguinal hernioplasty; division of right cord (11/28/34)	Right O. K.; left, atrophy	Right, recurrent 3 mo.; left, no	27 mo.
13	A. H. (No. 371891)	57	10 yr. ago right inguinal hernioplasty; recurrence 7 yr. ago	Recurrent right inguinal hernia	Hernioplasty; division of right cord (10/8/34); postoperatively; hematoma in wound and scrotum; destruction of testis	Orchidectomy		
14	A. M. (No. 350209)	75	30 yr. ago, right hernioplasty; 10 yr. ago recurrence; 1933 right hernioplasty for recurrence; 2 mo. ago left inguinal hernia	Left inguinal hernia (direct-indirect)	Hernioplasty; division of left cord (10/2/34); postoperatively: left cord became thickened to 2 cm.			None
15	J. S. (No. 375162)	42	Bilateral hernias several year ago	Large direct-indirect on right; small on left	Bilateral hernioplasty; division of right cord (12/34)	O. K.	Small recurrence (right)	28 mo.
16	B. M. (No. 381374)	42	6 mo. bulge on right side	Bilateral hernia	Bilateral hernioplasty; division of right cord (6/24/35)	Atrophy	No	20 mo.
17	B. H. (No. 390380)	43	1933 hernioplasty for ventral hernia	Left indirect inguinoscrotal hernia	Hernioplasty; division of left cord (2/36)	O. K.	No	12 mo.

TABLE I—CONT'D

CASE NUMBER	NAME	AGE	HISTORY	DIAGNOSIS	OPERATION	FATE OF TESTIS	RECURRENCE OF HERNIA	PERIOD OF FOLLOW-UP
18	I. S. (No. 395466)	56	Right hernia, 20 yr.; left hernia, 5 yr.	Bilateral inguinal hernia	Bilateral hernioplasty 2 stages; division right cord (3/10/36)	Right epididymis thickened; testis O. K.	No	24 mo.
19	R. G. (No. 397303)	56	Right inguinal swelling about 1 yr.	Right direct-indirect hernia	Hernioplasty; right cord divided (8/36)	O. K.	No	24 mo.
20	J. W. (No. 403085)	47	Lump in right scrotum 5 mo.	Right scrotal hernia	Hernioplasty; right cord divided (1/6/37); postoperative reaction in cord	?	?	
21	J. Z. (No. 403204)	47	5 yr. bulge in left groin	Left indirect inguinal hernia	Hernioplasty; left cord divided (1/6/37); postoperative reaction in cord	Atrophy and thickening	No	11 mo.
22	J. M. (No. 382647)	55	8 mo. bulge in left groin	Left indirect inguinal scrotal hernia	Left hernioplasty; left cord divided (7/27/37)			
23	J. B. (No. 383425)	51	Lump in right groin for many years held in place by truss; recent occasional irreducibility	Right direct-indirect hernia (inguinal)	8/17/35	O. K.	No	16 mo.
24	J. G. (No. 404118)	39	1915, induced hernia; 3 hernioplasties with recurrences	Recurrent direct-indirect inguinal hernia	Left hernioplasty; left cord divided (2/5/37)	Atrophy one-third size	No	14 mo.
25	G. M. (No. 437062)	37	Lump in right groin and scrotum, 3 yr.	Sliding hernia of cecum	Right hernioplasty; division of right cord structures (3/6/39); postoperative testicular swelling and infection of wound	?	No	6 mo.

cord were severed thirty-one months before offered clinching evidence to support the clinical impression of testicular viability. This case (H. C., Case 8) warrants special presentation.

CASE REPORT.—The patient was a man 20 years old in whom a right hernioplasty was performed three years previously. There was a recurrence of the hernia within seven months. On May 29, 1936, hernioplasty was performed for the recurrence and the whole right spermatic cord was severed in order to effect tight closure. There has been no recurrence of the hernia. The recent development of swelling and a sense of a mass in the right testis led to its removal for suspected neoplasm thirty-one months after the cord structures were severed. At operation the spermatic cord was exposed and no pulsation could be felt in the spermatic artery. The testis, epididymis, and vas up to the external ring were removed.

Gross Pathologic Description.—"Specimens consisted of a resected testis and epididymis and 8 cm. of the spermatic cord. Upon opening the tunica vaginalis there was revealed a testis normal in size and shape, measuring 4.5 by 3.5 by 2.3 cm. The epididymis also appeared normal in size and shape. On section, the body of the testis presented a tawny cut surface which was somewhat edematous. The tubules could be strung with ease. No areas of atrophy or fibrosis were evident. Section through the epididymis disclosed nothing unusual. The structures of the spermatic cord presented no abnormalities." (Fig. 5.)

Microscopic Description.—(Figs. 6 and 7.) "The seminiferous tubules appeared somewhat reduced in number and rather widely separated from each other, as though by edema of the interstitial tissue. However, there were no fibrous or hyaline tubules such as one sees in the usual areas of tubular atrophy in the testis. Many of the tubules appeared somewhat dilated. This appearance is enhanced by a reduction in the cells of the tubules. All stages of spermatogenesis were observed, although the sum total was reduced. In addition to this quantitative variation from normal there were certain qualitative aberrations. In some tubules complete inactivity was evident. In others there seemed to be some abnormality in the transformation of spermatids into mature spermatozoa. The latter lacked for the most part the usual elongated spearheads. The heads appeared, instead, round. Tails were not found. This may have been due to inadequate fixation. Some of the tubules contained a homogenous, basophilic coagulum. The number, appearance, and distribution of the interstitial cells were normal. The blood vessels were unchanged. The structures of the epididymis were not unusual. A few tubuli epididymides contained small numbers of round-headed spermatozoa whose tails could not be distinguished."

This case is unique in that we were able to study microscopically for the first time the late effect of complete severance of the spermatic cord (almost three years after the operation). The findings prove that the testis was only insignificantly altered following complete division of the cord.

TECHNIQUE OF OPERATION

The technique of severance of the cord is simple. Each structure is tied off by separate suture. Mass ligatures are not employed. The cord should be tied off above the scrotum, between the external and the internal abdominal rings. Ligature of the cord structures in the scrotum, at or below the external ring, destroys any possible collateral anastomosis. It is evident that meticulous aseptic and hemostatic technique is

required, otherwise a resultant hematoma dissecting along planes into the scrotum will interfere by compression with the collateral circulation. Infection may lead to the same result if the scrotum becomes involved. Should there be any indication of hemorrhage or infection, immediate opening of the entire wound and evacuation of the dissecting clot or pus is necessary in order to relieve compression of collateral vessels.

A study of our cases demonstrates that there is little or no apparent effect upon the testis and the epididymis in the majority of cases if a careful technique is employed. A maldescended testis is variable and displaced, and severance at any point might interfere with the collateral circulation.

SUMMARY

1. The testiculoepididymoscrotal arterial and venous systems comprise a potential collateral circulation for the testis in case of complete severance of the structures of the cord in the inguinal canal.

2. The severance of all the structures of the cord in 24 cases resulted in no immediately obvious abnormality in the testis.

3. In an adequate follow-up of 19 of these patients over a period of eight to fifty-five months, very little or no atrophy was observable in 13 patients (68 per cent) and obvious atrophy in 6 patients (32 per cent).

4. Microscopic study of the testis removed in one of these cases thirty-one months after complete severance of the structures of the cord revealed an essentially normal testis.

5. A careful aseptic and hemostatic technique is an essential factor in safeguarding the development of a collateral circulation, and thus preserving the testis in the majority of cases.

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THE BIFURCATION OPERATION

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THE operative procedure which has become known as the "bifurcation" operation was apparently first described by Lorenz,[5] although he admitted the similarity in principle of this operation to other types of subtrochanteric osteotomy used by Kirmisson[4] and previous to that by other American surgeons. Lorenz was of the opinion that special merit accrued to the particular osteotomy which he recommended. Originally suggested by the observation of a pseudoarthrosis of the femoral neck, the rationale of its application to other conditions, and especially to the treatment of irreducible dislocations of the head of the femur, was quickly recognized. In addition, it has been recommended in a number of different conditions: upward dislocation of the femoral shaft following a destructive epiphysitis, fractures of the acetabulum, nonunited fractures of the femoral neck, and the painful coxarthritides in which ankylosis has not occurred.[1, 2]

In essence, the operation constitutes an effort to divert the stream of body weight, so as to restore stability without sacrifice of hip joint mobility. Although the procedure makes no attempt at restoration, either of normal anatomy or physiology of the injured hip joint, there is no doubt that it does succeed, in many cases, in rehabilitating the functionally incapacitated patient. It is a relatively simple technical procedure, which can be quickly performed, with but little shock. It actually does re-establish stability in the unstable hip joint. It relieves pain and permits of at least partial physiologic rest to an inflamed or otherwise irritated joint.

It would seem to be exactly the sort of operative intervention which should have fired the imagination of the orthopedic surgeon. This is not the case. With the exception of some few who insist upon its merits, the procedure does not seem to have won general popularity. It is interesting to note that it is particularly in the treatment of the unreduced, congenital dislocations, for which the operation was originally recommended, that the greatest dissatisfaction has been manifested.

In the main, the objections have been twofold. The first of these is concerned with the apparent development of a postoperative knock-knee. Although some have claimed, and quite reasonably, that the abducted position of the distal portion of the femur predisposes to the formation of a genu valgum, others have insisted that this was merely apparent, or was present before operation. This moot point can be readily determined by pre- and postoperative axial measurements and does not

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appear to be of critical importance. Even if it could be established that genu valgum is the invariable sequel of the operation, the condition is so readily amenable to correction by supracondylar linear osteotomy that it should not be urged as a valid contraindication to the operative intervention, provided the intervention were otherwise satisfactory.

By far a more serious objection, and undoubtedly the one which accounts for the lack of popularity of the operation, is the interference in mobility which, in varying degrees, has been observed almost routinely. It is this disability which forms the main theme of the present communication. Before proceeding to its consideration, a third objection, not previously stressed, should be noted.

Because of the satisfactory results obtained in adults, the indications for the operation have been extended to include the treatment of similar conditions in children. However, experience soon showed that, even in the hands of the same surgeon, the response of children to the bifurcation procedure might be entirely different from that seen in adults. In the latter, the shape given to the femur could, with confidence, be expected to remain unchanged. In children, on the contrary, it was observed that even in cases in which "ideal" bifurcation had been performed, the "spike" of the distal fragment tended to disappear. The femur gradually lost its given configuration and with the lapse of time assumed a form reminiscent of that obtained after a Schanz type of osteotomy.[6] Although this was explained as an inherent response of growing bone to the altered stresses occasioned by the osteotomy, the disappearance of the projecting and presumably supporting upper end of the distal fragment was disconcerting. Indeed, it almost seemed to contraindicate the use of the operation in children.

But even this did not seem to exhaust the difficulties which these patients presented. Further observation recalled almost paradoxically that, while instability might be the consequence of a loss of the bifurcation configuration, pain and limitation of motion persisted in certain cases in which the bifurcation was not lost.

CASE 1.—Marjorie G., aged 6 years, was seen in the Outpatient Department in June, 1932, with a history of a peculiar gait since the age of 2. Examination disclosed a bilateral congenital dislocation, with all the classical signs and symptoms. Because of the fact that the acetabular fossae seemed to be largely replaced by bone reposition, simple reduction was deemed inadvisable, and anterior transposition, after preliminary traction, was decided upon. By means of Hoke traction, the femoral heads were pulled down to about the acetabular level. Adduction tenotomy was performed, and anterior displacement of the femoral heads was undertaken. Although it appeared to have been successfully carried out, the result as to stability was not considered satisfactory. The patient was consequently readmitted to the hospital, and bifurcation was performed on the left hip in January and on the right hip in March, 1934. The convalescence was of a routine nature, and the patient was discharged from the hospital in April, 1934. In June, 1934, it was noted that internal rotation was limited, that adduction was painful, and that flexion, which was limited, occurred only on external rotation. The

roentgenogram (Fig. 1) taken in August, 1934, showed what appeared to be Schanz osteotomies performed at different levels. In November it was noted that the child complained of pain and walked with a peculiar waddling gait. Because the Trendelenburg sign was negative, the waddle was attributed to fear and muscle weakness.

As time went on it was noted that on the right side pain and the waddle persisted. On the left side these disappeared with recurrence of instability. In February, 1937, the roentgenogram (Fig. 2) disclosed a loss of the typical configuration on the left side, with its persistence on the right.

Fig. 1.—Case 1. Roentgenogram made in August, 1934, after bilateral osteotomy.

Because of the firm belief in the necessity for pelvic support, the pain and limitation of motion on the one side, at the time, was unfortunately overlooked. Interest centered mainly on the other side, and the apparently bizarre outcome was accepted, without more ado, as another one of the bifurcation peculiarities which had been observed repeatedly in adults. In many adult cases in which "unsatisfactory" bifurcation had been performed, the functional result was frequently excellent, although the roentgenographic appearance left much to be desired. Instead of bifurcation, osteotomy, either at a high or a low level, had been performed. Even where the osteotomized fragment made no contact with the pelvis, stability had been restored, without any material limitation of motion. Yet, strange to relate, it was frequently noted that the greatest disability appeared precisely in those very cases which presented the most typical roentgenographic evidence of anatomically "satisfac-

tory'' bifurcation. Since by far the greater majority of the bifurcation operations had been performed for unilateral indications, the disability did not appear to be sufficient to justify the casual discard of the procedure. Although the patient's complaints of pain could not be entirely disregarded, they were accepted as representing the price paid for the acquisition of stability by means of a relatively simple operative intervention. It was only when a review of the bilateral bifurcations was undertaken that the extent of the disability was fully appreciated and a clue to its causation was found.

Fig. 2.—Case 1. Roentgenogram made in February, 1937. The angle of the upper end of the right femur is approximately that of the pelvic wall. On the left side, the angle is definitely less.

A strikingly similar clinical picture was discovered in all. There was an annoying increase in the intercrural distance, with an inability to bring the legs into parallelism. The patients could not completely flex or adduct the thighs. In the seated position they could not cross their legs tailor-fashion. They could not assume the squatting position and had difficulty in putting on their shoes or stockings. In the erect position, they stood with the legs abducted and the feet everted. Forward progress was possible only with a peculiar twisting and waddling gait. Nevertheless, the Trendelenburg sign was invariably negative. Pain was present in varying degree. In some patients the pain was so mild that it was overlooked in their satisfaction at the restoration

of stability. In others, it was so severe that the patients insisted on relief, even at the risk of reoperation.

In these cases one factor appeared to be constant. Roentgenographically, all showed good bifurcations, but in all a long spike, formed by the upper end of the osteotomized fragment, persisted. The obvious inference was that this was the cause of the difficulty; the obvious indication was for its removal. But, since the spike is of the very essence of the bifurcation operation, its removal seemed to imply a negation of the previous surgical effort. Without further consideration, this did not

Fig. 3.—Case 2. Roentgenogram made in February, 1934, after the first bilateral bifurcation operation.

seem warranted. It was at this stage that the experience with the bifurcation operation in children came to mind. As has already been noted, instances had been observed in which stability was preserved, despite the loss of the spike. It seemed, therefore, justifiable to reproduce, surgically, the effects which nature had demonstrated in children.

With this object in view, several patients were admitted to the hospital for the specific purpose of resecting the projecting spike of the distal osteotomized fragment. The two cases herewith recorded are typical.

CASE 2: *Bilateral bifurcation for congenital hip dislocations, with subsequent removal of persisting bone spike on left side.*—Mary M. was seen in July, 1932,

at the age of 12 years. She presented all the pathognomonic signs of bilateral hip dislocation. This was confirmed by roentgenographic examination. Because of the high position of the femoral heads, preliminary skin traction, and later skeletal traction, was attempted, but without success. In 1933 adductor tenotomy and then anterior transposition of the femoral heads were carried out to balance the pelvis and overcome the marked lumbar lordosis. The roentgenogram showed the position of the femoral heads beneath the anterior iliac spines. The results of this transposition were not satisfactory, and bifurcation was recommended to overcome the waddle and establish stability.

In November, 1933, bifurcation was performed on the right side. In January, 1934, bifurcation was performed on the left side (Fig. 3). In both instances the effort was made to place the upper end of the distal fragments into the acetabula, according to the precepts of Lorenz and of Haas.[3] On the left this was accomplished but on the right side the effort failed. In March, 1935, it was found that both bifurcations had lost their characteristic appearance and had assumed almost their preoperative appearance (Fig. 4).

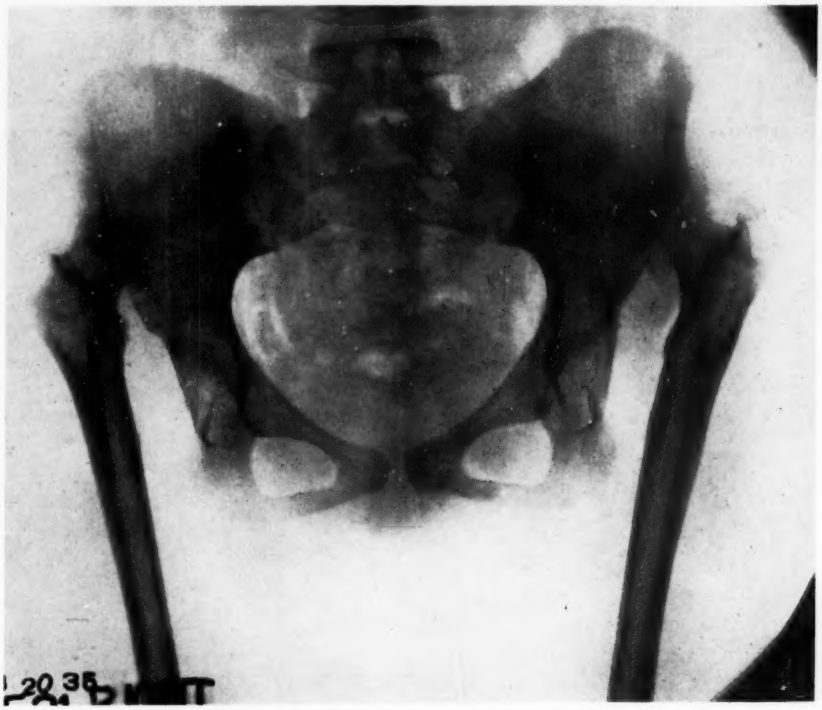

Fig. 4.—Case 2. March, 1935. The bifurcation has disappeared. It is barely possible to recognize that osteotomy has been performed.

Because of the persistence of the waddling gait, operative revision of the bifurcation was advised. This was performed on the left side in October and on the right side in December, 1935. A roentgenogram taken in April, 1936 (Fig. 5) showed good bilateral bifurcation. It is to be noted that the anatomic appearance on the right side is almost that of a Schanz osteotomy. On the left side there is a well-formed spike, which is placed directly in the acetabulum, and the femoral head does not appear to be in close contact with the pelvic wall. Even after this revision, the result left much to be desired. In 1938 the patient still walked with a peculiar twisting waddle. She was unable to cross her legs or to

Fig. 5.—Case 2. April, 1936. Roentgenogram made after second bilateral bifurcation.

Fig. 6.—Case 2. June, 1939. On the left side the bifurcation character has been preserved. The projecting spike, with the head, forms an angle greater than the angle of inclination of the pelvic wall.

walk with the left foot pointing forward. There was moderate limitation of motion in all arcs of motion on the left side.

	RIGHT	LEFT
Flexion	Complete	90°
Extension	175°	180°
Abduction	70°	60°
External rotation	60°	50°
Internal rotation	30°	5°

A roentgenogram (Fig. 6) taken in June, 1939, disclosed the startling explanation of these phenomena. On the right side the bifurcation had again lost its characteristic form, but on the left the spike had persisted. Lateral views, not reproduced here, demonstrated the forward projection of this bony prominence.

Fig. 7.—Case 2. July, 1939. The spike has been amputated, with prompt restoration of motion.

In the conviction that this was the cause of the patient's disability, resection of the bony block was advised and carried out in June, 1939. On the operating table it was clearly demonstrated that the limitation of internal rotation was caused by this spike, and that immediately upon its removal the limitation dis-

appeared. The patient's convalescence was uneventful, and she was permitted out of bed as soon as the soft tissue wound had healed. Even as early as several weeks after operation, the patient showed a marked improvement in gait. The stability was well preserved, and, bearing her full weight, the patient was able actively to rotate her left leg internally to 20°. Forward progression was possible in a normal manner, with only a slight limp and pelvic tilt. The roentgenogram (Fig. 7) taken in July, 1939, revealed that the spike had been completely resected.

CASE 3: *Bilateral congenital femoral dislocation treated by bifurcation and subsequent amputation of "spikes."*—Emma S., aged 27 years, was seen in the Outpatient Department in March, 1937. There was a history of a limp, waddling gait, and difficulty in standing and walking since childhood. The recent appearance of pain in the hips forced the patient to seek medical assistance. Physical examination disclosed all the classical signs of a bilateral, congenital, femoral dislocation. An x-ray taken in March, 1937, showed "bilateral, congenital dislocation with [it is to be noted] adduction deformities of both femora. The newly

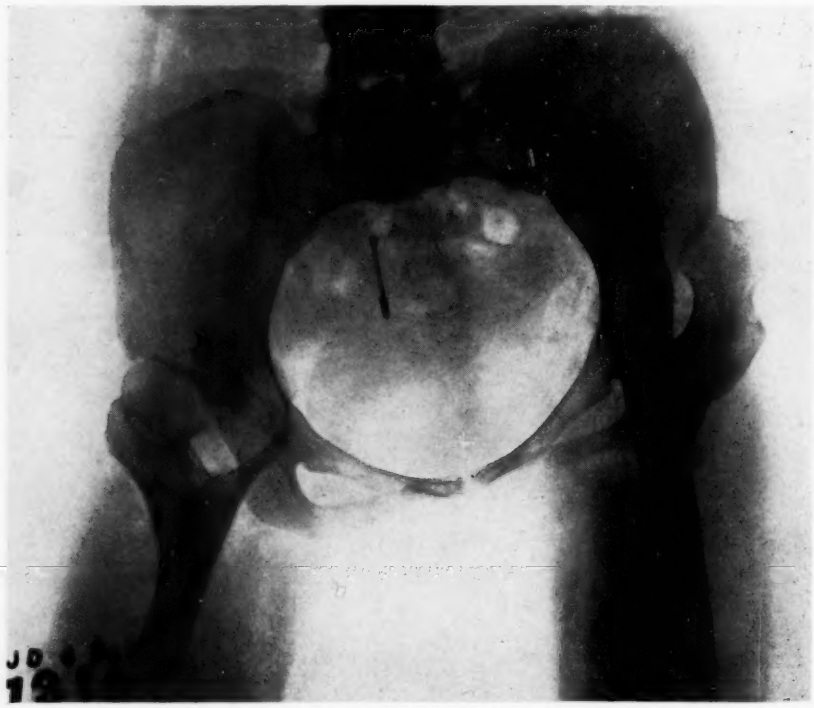

Fig. 8.—Case 3. April, 1938. Roentgenogram made after bilateral bifurcation. The angles of the upper end of the femur are obviously greater than the angle of pelvic inclination.

formed acetabulum on the right side shows marked, productive changes." In March, 1937, bifurcation of the left femur was performed in the oblique sagittal plane. The postoperative convalescence was uneventful, and in August, 1937, the patient was readmitted for a similar bifurcation of the right femur. The patient was discharged, walking with crutches, in November, 1937.

In January, 1938, the patient complained of severe pain in both groins. She noted that the right leg seemed longer than the left. She walked in a guarded manner, the right leg held in marked abduction and external rotation, with the knee in flexion. The left leg was in less marked abduction and external rotation.

As in the right leg, internal rotation was impossible, either passively or actively. The patient could not adduct her legs in standing or cross her legs in sitting. She was given physiotherapy and encouraged to discard her crutches, but without any subsequent improvement in gait or comfort. A roentgenogram taken in April, 1938, disclosed the reason for the disability; the upper ends of the distal fragments were found to abut anteriorly against the acetabular rim and not against the ischial tuberosity, as had been previously reported (Fig. 8).

The patient was readmitted to the hospital for the purpose of removing this abutment on the right side. At operation, the upper end of the distal fragment was found in contact with the pelvic wall, anterior to the acetabulum. Internal rotation of the femur was prevented by the bony prominence, even with the leg in abduction. The spike was partially removed, and immediately thereafter there was marked relief of pain in the right groin. The patient was able to flex the thigh, but only on abduction; the power of adduction improved, but internal rotation remained limited, probably because of insufficient removal of the bone spike. Following her discharge from the hospital, there was marked improvement noted in the gait, but she continued to complain of pain in the left groin.

Fig. 9.—Case 3. January, 1940. The spike has been largely amputated on the left side, with excellent restoration of function. On the right side partial amputation resulted in continued impairment of function.

In November, 1938, the patient was again admitted for operation on the left side. The spike of the distal arm of the bifurcation was found projecting forward into the thigh musculature. When an effort was made to bring the leg into the neutral position, the spike impinged against the side of the pelvis. From the experience gained at the previous operation, it was realized that a more liberal resection of the spike was necessary. Although complete removal of the bony projection was impossible, the result was more satisfactory than on the opposite side. There was an increased range of rotation and almost complete subsidence of the

pain. The postoperative roentgenogram of the left leg showed fairly satisfactory removal of the obstructing spike.

Upon her discharge from the hospital in December, 1938, the patient's right leg was still held in moderate abduction and external rotation. There was marked diminution in pain. The gait was greatly improved but was still unsightly, and the patient was unable to cross her legs when sitting. In January, 1940, a roentgenogram showed that, on the left side, the bifurcation had been converted into a modified Schanz osteotomy by removal of the spike. On the right side a truncated spike still persisted (Fig. 9).

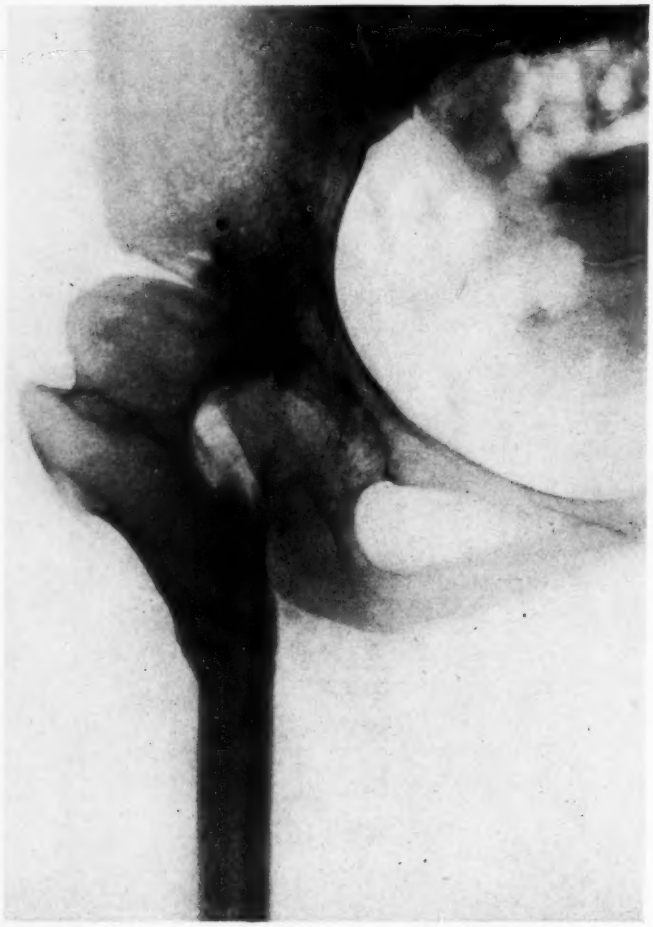

Fig. 10.—Case 3. February, 1940. After secondary resection of the spike on the right side, the patient was able to bring both legs into parallelism, with marked restoration of mobility in all directions.

The patient was admitted to the hospital for the removal of this bony projection. The day following operation she was able to stand erect with her extremities parallel. Within two weeks the patient could cross her legs. In the erect position, the legs could be held together. Rotation, flexion, and abduction were almost normal. She walked with the feet pointing forward. There was still a slight waddle, but the twisting component had disappeared. The stability was excellent, and the Trendelenburg sign remained negative. The pain had completely subsided. The roentgenogram taken in February, 1940, showed marked reduction in the size of the projecting spike (Fig. 10).

The study of these and other cases established beyond question that, even in the hands of the same surgeon, the response of children to the bifurcation procedure was entirely different from that seen in adults. Whereas in adults the form given to the femur could with confidence be expected to remain essentially unchanged, in children it was found that with the lapse of time the given shape became so modified that the results observed shortly after operation differed radically from those noted at later examinations. During the early period, in children, stability was without exception restored. Where excessive abduction, unduly prominent spike formation, or improper double contact with the pelvis occurred, a marked impairment of gait and even painful limitation of motion were commonly seen. But almost invariably these unpleasant sequelae gradually disappeared as the children grew older. The pain subsided and the gait improved, but all too frequently the previously acquired stability vanished at the same time. When the roentgenographic series of these patients was examined, it was found that, as the stability disappeared, the femora manifested a typical sequence of variation. Beginning with the characteristic "Y" shape of the Lorenz bifurcation, the femur assumed the hockey-stick shape of the Schanz osteotomy and tended ultimately toward the original shape of the bone.

In the instances where this did not occur, it was found that, as in adults, pain and limitation of motion were invariably associated with excessive abduction or spike formation. In the unilateral cases, and in the erect position, this interference in motion is marked by tilting of the pelvis. The degree to which such compensation can occur is determined in large measure by the mobility in the opposite hip and the sacrolumbar articulations. When seated, the possibility of pelvic tilt is precluded and the characteristic limitation of motion is readily demonstrable. These patients cannot cross their legs; they have difficulty in putting on shoes or stockings, and they cannot sit on low chairs. However, it is in the bilateral cases that the full extent of the disability becomes apparent. When the abduction of the distal fragment makes an angle with the femoral neck which is greater than the angle of inclination of the outer pelvic wall, these patients cannot bring the legs into parallelism for normal progression. As a result, the gait is awkward and may best be described as a twisting waddle, which persists despite a negative Trendelenburg sign. The feet are held everted, and rotation is markedly limited. In addition, the patients not infrequently are afflicted with such pain in the groin that they insist upon relief.

In children, the disability may disappear spontaneously as the upper end of the femur loses the appearance of bifurcation. Where this does not occur and where the spike persists, these young patients suffer the disturbances which are seen in their elders. In these the same tendency

toward loss of the bifurcation may be noted occasionally, but the rate at which this change occurs is relatively so slow that a more expeditious therapy must be instituted.

These disabilities can be promptly overcome by resection of the spike which is the hallmark of the bifurcation operation. The fact that this can be accomplished with restoration of mobility and without loss of stability seems to indicate clearly that the spike is not essential to the successful outcome of the osteotomy, and that, on the contrary, it is the cause of the undesirable effects almost routinely found after a typical bifurcation operation.

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THE APOPHYSEAL INTERVERTEBRAL JOINTS

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OBJECT OF STUDY

OF THE two forms of joints in the vertebral column, only the apophyseal joints, which connect the neural arches, are true diarthrodial articulations. They differ from the synchondroses formed by the disk and vertebral bodies almost as much as the hip joints from the pubic symphysis. In the pathology of the spine this difference is more important than is generally appreciated; it seems to have been recognized first by Fraenkel,[5] in 1903, but its clinical significance is not yet fully known. Lesions of the apophyseal joints are not easily interpreted. The joints may be involved in various affections of the vertebral bone, but they may be affected independently by the different forms of arthritis, in which case other vertebral parts in turn may become involved. Hence, it is difficult to distinguish primary from secondary or incidental lesions. Reactions usually considered characteristic, such as osteophytes, rarefaction, calcification of ligaments, or destruction of cartilage, are common to many vertebral diseases and may develop after the primary lesion is healed. Since most vertebral diseases take a chronic course, post-mortem examination usually shows the multifarious consequences rather than the primary or essential features of the morbid condition. Relevant features, e.g., of arthritis, may thus escape verification. Within its own limits, roentgenologic study shows at least some of the stages of the pathologic process and reveals quite frequently the anatomical condition present at the time of the clinical examination. Correlations between anatomical and clinical findings can hardly be analyzed in another way. This report is concerned with the anatomical characters of the lesions involved, with their classification, and with the clinical manifestations observed.

RADIOGRAPHIC METHOD

As late as 1936 it was held that involvement of the apophyseal joints cannot be shown on radiographs.[7] Methods of x-ray examination and significant findings were described for the lumbar spine in 1929,[3] 1931,[11] and 1934;[6] for the thoracic spine in 1934;[13] and for the entire spinal column in 1938.[17] The radiographic positions are determined by the angles which the joint spaces or the corresponding facets* form with the frontal plane: 90 degrees in the cervical section, nearly 20 degrees in

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*The terms apophyseal joint, articular process, and facets are often used synonymously. The facets are the bony surfaces of the articular process to which the cartilages of the apophyseal joint adhere. The apophyseal joints are often referred to as small, posterior, lateral, or intervertebral joints.

the dorsal section, and 45 degrees in the lumbar section (Fig. 1). The direction of the facets is constant in the cervical and thoracic regions, but it varies individually in the lumbar spine where the facets of caudal segments may be rotated forward more strongly than those of superjacent ones. This results in abnormal projections easily mistaken for morbid changes (Fig. 2). In the dorsal spine, where the articular processes are flat and slender and the joint spaces narrow, inaccurate technique results in pictures that cannot be interpreted (Fig. 2).

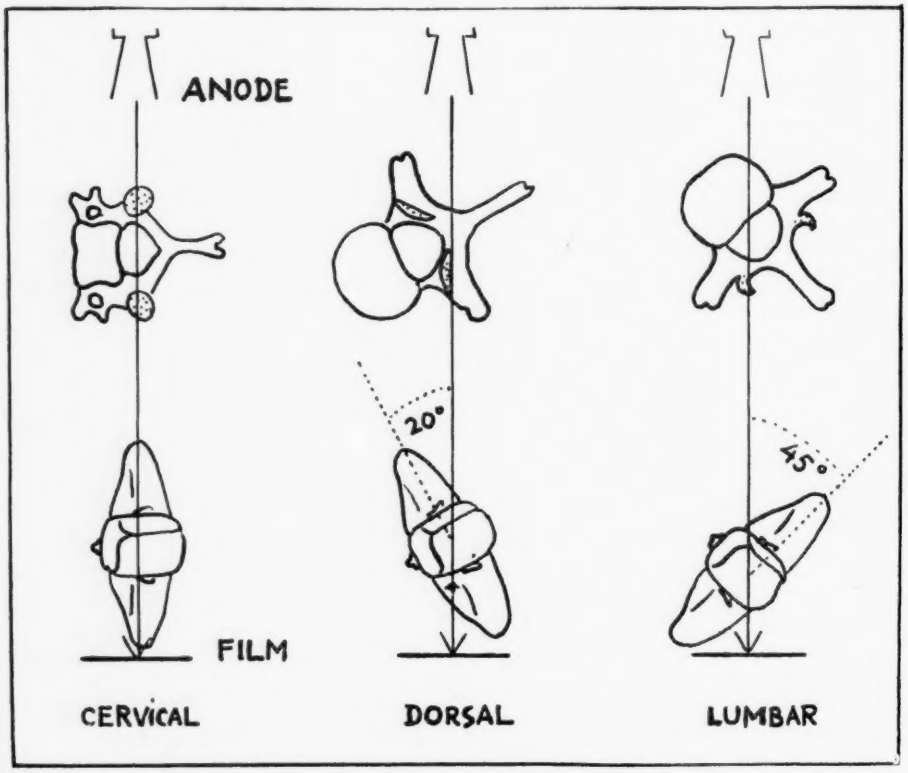

Fig. 1.—Radiographic method for demonstration of the apophyseal joints.

DEVELOPMENTAL VARIATIONS AND ANOMALIES

The articular processes may vary appreciably in size, shape, and position in the same segment; they are always broader and shorter in children than in adults (Fig. 3). In the newborn a radiolucent interspace, corresponding to the epiphyseal cartilage between vertebral body and neural arch, is seen slightly ventral of the apophyseal joint (Fig. 3). It ossifies usually in the course of the first five years. Gaps in the tips of the articular processes and in the isthmus or interarticular portion (Fig. 4) correspond to abnormally persistent cartilages separating bones which originate from distinct centers of ossification.[1, 2, 4, 8, 10, 24] A peculiar supernumerary bone adjacent to a nonossified isthmus is shown in Fig. 4; this anomaly seems to have not yet been recorded. Hypoplasia

or complete absence of articular processes is rather common when combined with other developmental disorders, but it is rare as an independent occurrence (Fig. 3). The articular processes of block vertebrae may be fused. Synostosis of the articular processes only is not uncommon in the upper cervical segments (Fig. 3). A supernumerary apophyseal

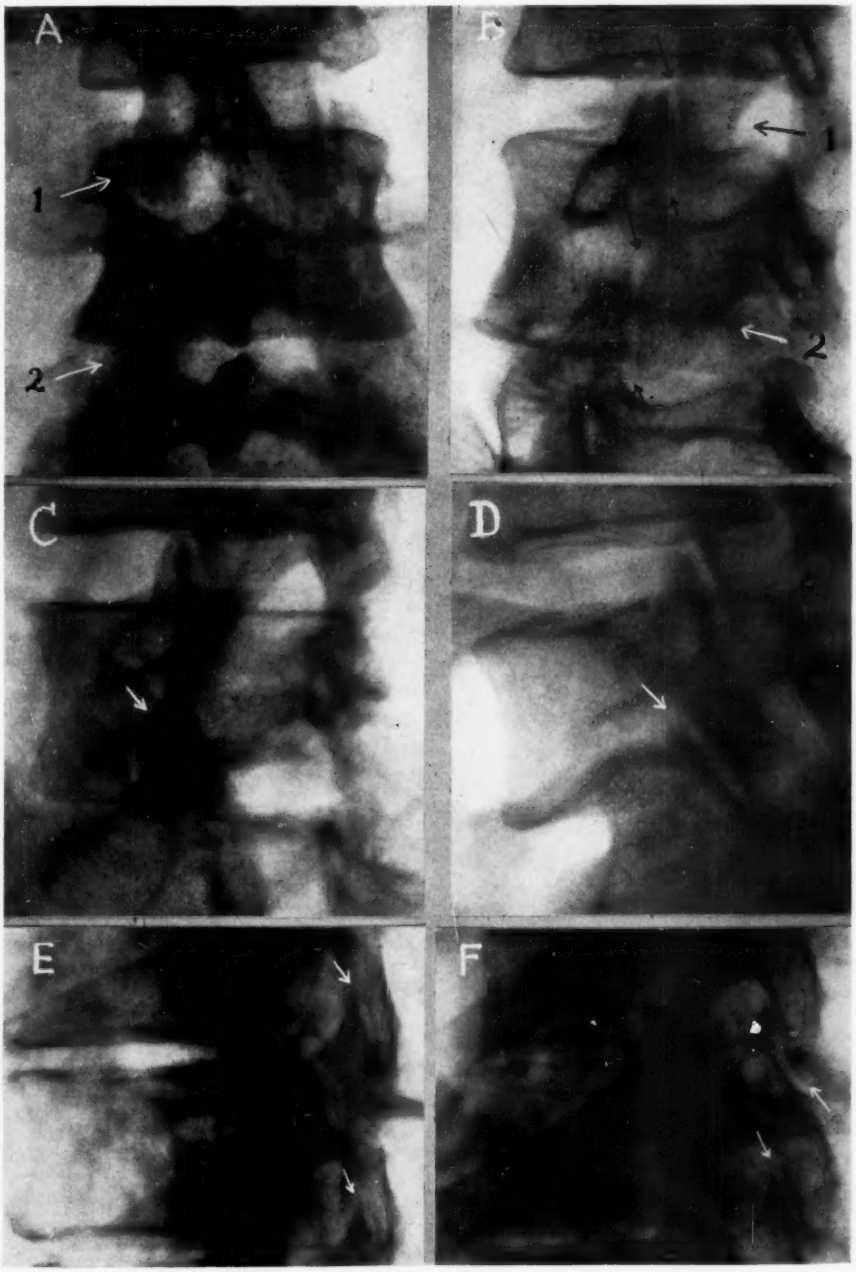

Fig. 2.—Sources of errors. In the sagittal view (*A*) two facets appear to be ragged and their joint spaces narrowed (*arrows*); but the oblique view (*B*) shows that they are normal. Owing to faulty positioning (*C* and *E*) the joint spaces appear ankylosed, but correct projections (*D* and *F*) show normal joints (*arrows*).

joint may be present between the first and second sacral vertebrae, especially when their transverse processes are not completely fused (lumbarization) (Fig. 3).

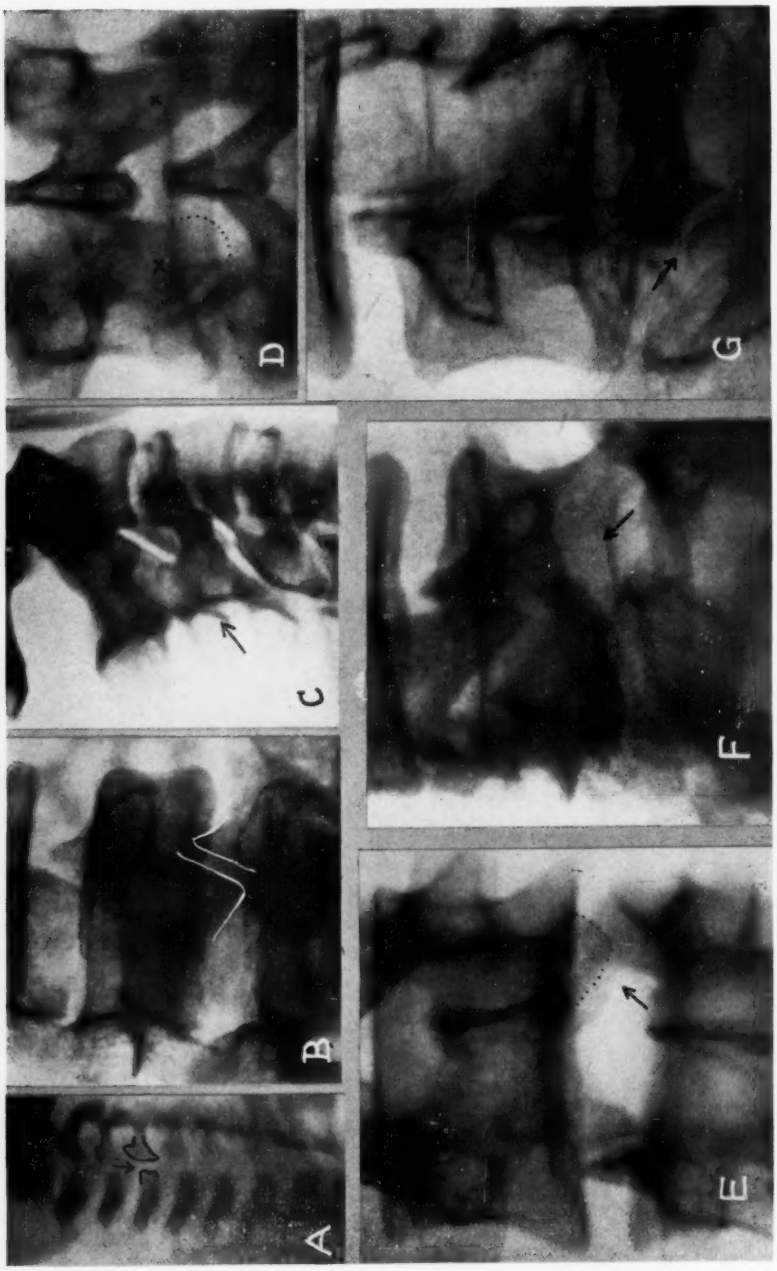

Fig. 3.—Developmental variations. Cervical spine of a newborn (*A*) with normal gaps between bodies and arches. In a boy, aged 12 years (*B*), the articular processes are broad and short. In a woman, aged 20 years (*C*), there is a synostosis between the second and third cervical articular processes. In a young man (*D*) the articular processes of the same vertebra differ in size, shape, and position. Hypoplasia (*E*) and aplasia (*F*) of inferior articular processes. Supernumerary joint (*G*) between first and second sacral vertebrae.

ARTHRITIS

The roentgenologic interpretation of arthritis is not built on firm ground. Apart from technical limitations, difficulties and confusion

arise from the combining and overlapping of morbid processes that are usually believed to be distinctive. For instance, bone atrophy, considered as typical of atrophic (rheumatoid) arthritis, occurs in both main types of arthritis;[12] whereas, condensation and osteophytes, which are regarded as criteria of hypertrophic (osteo-) arthritis, may develop also in the atrophic form when the articular bone has sufficient vitality to react by hypertrophy to the stimulation which results from the loss of cartilage.[12] Severe inflammation, irrespective of its etiology, is always

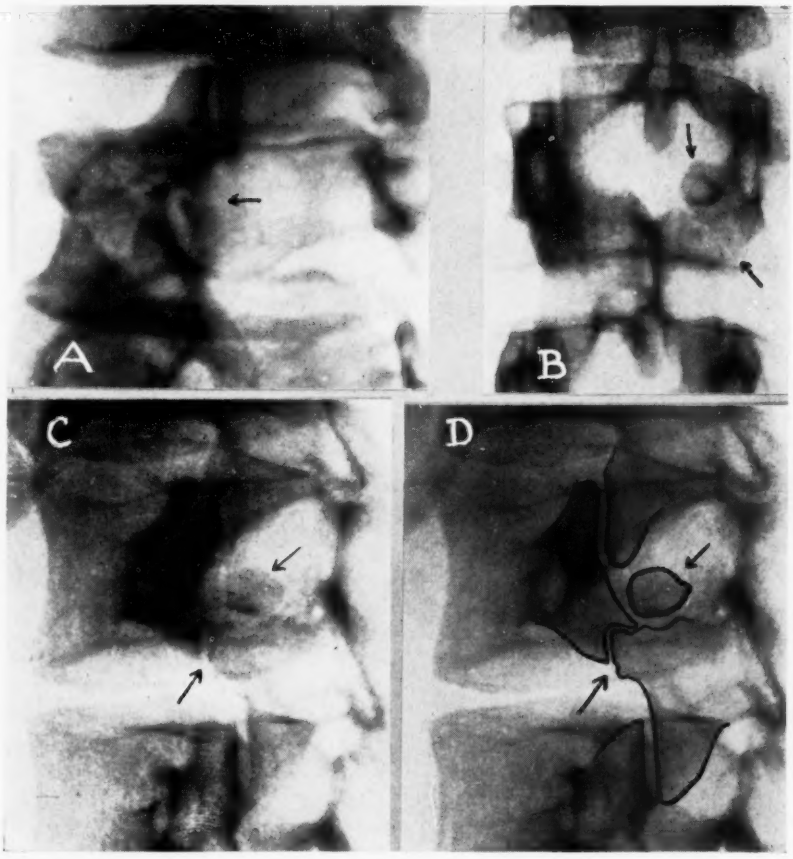

Fig. 4.—Gap in tip of articular process of lumbar vertebra (*A*). Sagittal view (*B*) and oblique views (*C* and *D*), showing gap in isthmus and a supernumerary ossicle close to it.

associated with rarefaction;[15] all being equal, a weak or oft-repeated stimulus elicits hypertrophy.[22] Infectious, toxic, metabolic, and mechanical influences are often intertwined. An infectious arthritis may be reactivated by mechanical or endocrine factors, and lesions caused by mechanical damage to cartilage are often aggravated by toxic or infectious influences. The alternation of inflammation and repair leads then to appearances difficult to analyze.

Bearing in mind that we are thus dealing with variable reactions to variable stimuli rather than with defined entities, we may follow the accepted distinction between an atrophic (rheumatoid) and a hypertrophic (osteo-) arthritic type, but without assigning to either a specific cause.

Atrophic (Rheumatoid) Arthritis.—One of its first stages is enlargement of the joint capsule. This is occasionally visible in the cervical segments, where the intervening soft tissues are thin enough to permit of visualization of the shadow cast (Fig. 5). Such a swelling of the joint capsule may occur also in joints involved by hypertrophic arthritis (Fig. 6 *C*). Slight rarefaction of the articular processes, stippled or diffuse, may coexist with the swelling in atrophic arthritis.[17] Atrophic arthritis may heal at this stage, and the shadow then disappears. If it progresses, the articular cartilage thins down, whereby the visible joint space becomes narrow (Fig. 5). Effusion, which often counterbalances this narrowing in other joints, seems to be very rare in the apophyseal articulations. Once destroyed, the cartilage is not regenerated to any appreciable amount or degree. The inflammatory pannus and cellular infiltration erode the subcartilaginous bone, and the facets become scalloped or ragged (Fig. 5). The disease may become arrested at this stage, at least for indefinite periods.[17] One of two reactions may set in subsequently. Either the denuded bone becomes condensed and rough (Fig. 5 *F*), whereby the atrophic merges with the hypertrophic form; or the inflammation may recur or progress and bony ankylosis between the facets take place (Fig. 5 *C*, *F*). Sometimes both forms of reaction are observed in the same vertebral column (Fig. 5 *F*). When bony ankylosis occurs, the ligamenta flava usually ossify together with the joint to which they adhere.

The lesion in its different phases may be confined to one or a few of the apophyseal joints;[17] it may also involve gradually those of the entire spinal column. The latter condition is invariably associated with all the clinical symptoms of rhizomelic spondylosis (Strümpell-Marie disease, ankylopoietic spondylitis or spondylarthritis, the Bechterew disease of the German nomenclature).

The roentgenologic study of rhizomelic spondylosis confirms the experience that autoptic findings are often misleading. "One does not die of rhizomelic spondylosis,"[14] hence post-mortem examination shows only the final result of this malady. Ossification of the longitudinal and yellow ligaments being common at advanced stages, the disease has been regarded as a form of spondylitis ossificans ligamentosa. Fagge's famous specimen, shown in Knaggs' article,[12] does not present ossification of the longitudinal ligaments. Léri, whose description is still unsurpassed, took great care to point out that ossification of vertebral ligaments occurs in many other lesions of the spine.[14] My studies suggest that vertebral ligaments may calcify or ossify in sections whose mobil-

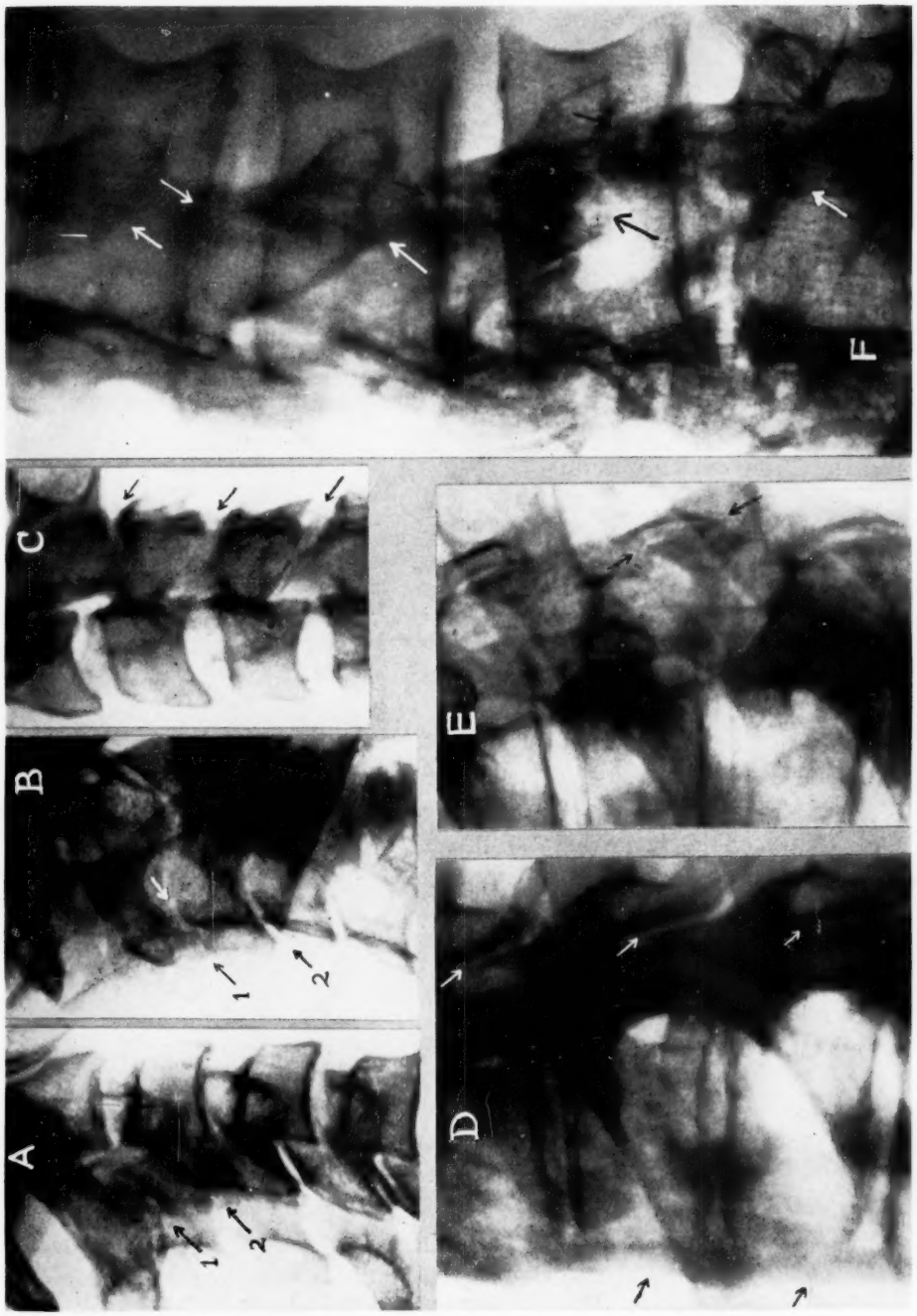

Fig. 5.—Atrophic (rheumatoid) arthritis. Lateral (*A*) and oblique (*B*) views, showing at *Arrow 2* a soft-tissue shadow corresponding to the swollen joint capsule, and at *Arrow 1* a narrowed joint space with ragged facets. Compare with the normal subjacent joints. Rhizomelic spondylosis or Strümpell-Marie disease (*C*) with ankylosis of apophyseal joints in the absence of ossification of ligaments; complete rigidity. Compare with *D*, dorsal spine of another case, showing ossification of anterior longitudinal ligament in the absence of lesions of apophyseal joints; no clinical symptoms whatever. Ankylosis confined to one dorsal joint (*E*). Rhizomelic spondylosis (*F*); spine rigid. The two upper joints are ankylosed; the two lower ones show ragged and condensed facets, showing that hypertrophic reactions may occur in the course of an atrophic arthritis.

ity is diminished for any of various reasons.[17] Where the disks are thinned, the longitudinal ligaments become flabby and tortuous, their ossification taking place in the form of protruding spicula. Where the disks remain normal in height, as in rhizomelic spondylosis, the ligaments remain stretched and ossify accordingly. This bamboo spine is one of the results, but it is neither a primary lesion nor a constant element of the morbid process; the longitudinal ligaments may fail to ossify in patients in whom complete ankylosis is unmistakable; in these, however, the apophyseal joints are invariably involved (Fig. 5 *C*). On the other hand, when the ligaments are ossified in the absence of apophyseal arthritis, clinical symptoms are not usually present (Fig. 5 *D*).

The vertebral bodies are often rarefied in rhizomelic spondylosis. Serial radiographs have shown that rarefaction is most severe while the arthritic inflammation is active; the vertebral bodies regain normal bone density when ankylosis between the facets has taken place.[17] We may assume that the vertebrae rarefy in this case like any other bone adjacent to an inflamed joint. Vertebral rarefaction and ossification of ligaments are perhaps interdependent. Connective tissue does not usually ossify unless neighboring bone is rarefied simultaneously.[15] This is a modern version of Marie and Léri's view that ossification of vertebral ligaments is a mode of healing, a reparative strengthening of the weakened spine, and merely an example of a general biologic rule.[14]

Hypertrophic (Osteo-) Arthritis.—As in other joints, its incipient stages cannot often be recognized radiographically in the apophyseal articulations. In the absence of definite bone rarefaction, narrowing of the joint space due to thinning of cartilage may suggest this lesion before bone hypertrophy develops. But, as above mentioned, such a finding may correspond also to a quiescent or arrested atrophic arthritis; the two forms may then be indistinguishable even histologically.[12]

When more advanced, hypertrophic arthritis is revealed by well-marked condensation of the articular processes. The joint space is narrowed. Osteophytes form at the edges of the facets. Contiguous exostoses may fuse and produce ankylosis of the joint (Fig. 6). Thorn-shaped prominences at the tips of the articular processes correspond to ossified insertions of intra-articular ligaments. This may be associated with hypertrophic spondylarthritis,[13] but it may also occur independently.[17] The two conditions should not be considered identical.

Hypertrophic spondylarthritis is not uncommon in the dorsal spine, where it often occurs in the absence of other vertebral lesions. In the lumbar section hypertrophic arthritis of the apophyseal joints is often associated with thinning of intervertebral disks. As the distance between vertebrae at the level of a flattened disk diminishes, the cartilages of the facets sustain increasing stress. Where the plane of the facets slopes diagonally backward, a posterior shift of the superjacent vertebra

results from thinning of the disk (Fig. 6). The subluxation may amount to bony impingement of the articular process upon the adjacent vertebra,[9] but the apophyseal cartilage may resist the strain.[17] This accounts for the fact that at the level of a flattened disk the apophyseal joints may remain normal; whereas, the corresponding vertebral bodies

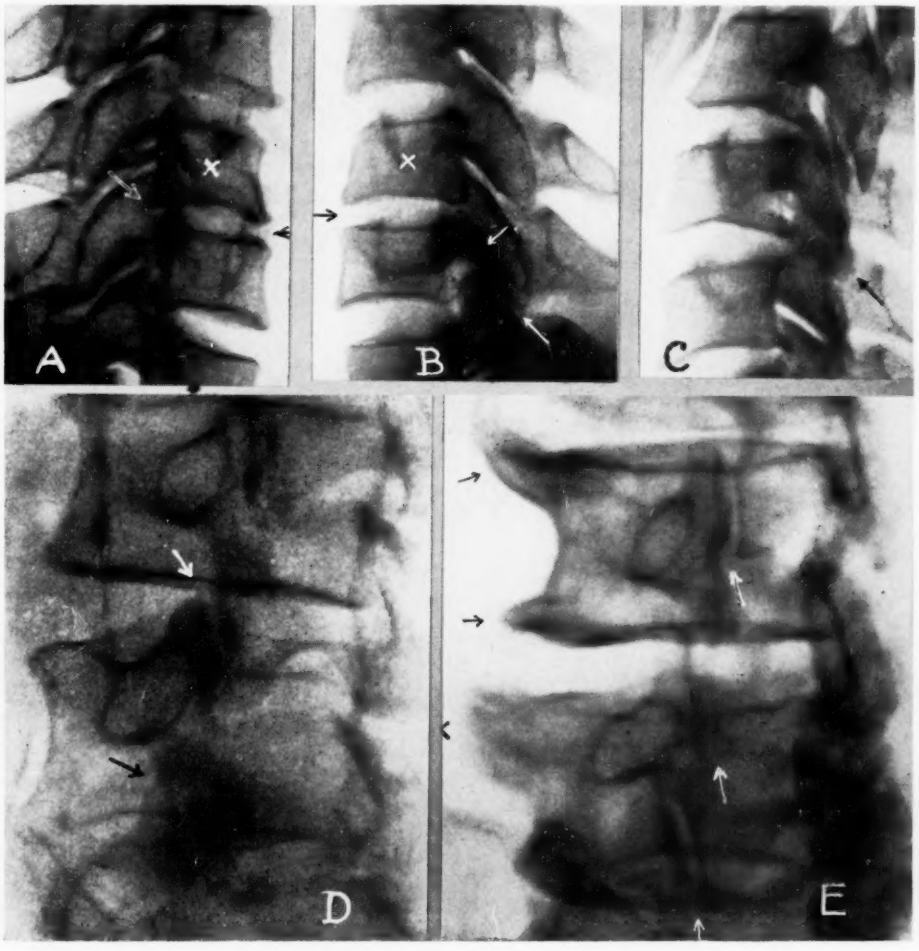

Fig. 6.—Hypertrophic (osteo-) arthritis. Thinning of fourth cervical intervertebral disk (*A*) with small exostoses at vertebral bodies, but without changes in the apophyseal joint. In another case (*B*) thinning of the same disk has not induced exostoses at the bodies, but narrowing of the corresponding joint space and condensation of the articular bone is present. Note that in either case the vertebral bodies above the thinned disk (*x*) are shifted backward. Hypertrophic arthritis (*C*) in the absence of other vertebral lesions. Note the shadow of the swollen joint capsule (*arrow*). Flattening of lumbar intervertebral disks: hypertrophic arthritis of apophyseal joints (*D*) in the absence of vertebral osteophytes; in another case there are large vertebral osteophytes (*E*), but the apophyseal joints are normal.

show large exostoses. In other cases the apophyseal cartilage is damaged while the vertebral bone fails to respond by hypertrophy to the mechanical irritation caused by disk flattening (Figs. 6, 8). In the first case it is the bone which reacts; in the second, it is the cartilage which is injured. These are clearly different reactions, but, since both are

often regarded as corresponding to the same lesion, namely, osteoarthritis of the spine, their failure to be always associated with disk thinning and with each other has given rise to extensive discussions and many discrepancies. I have suggested that lesions consecutive upon thinning of disks be designated as discogenetic in order to distinguish

Fig. 7.—Pott's disease; nineteen months' interval between *A* and *B*. Neural arches and articular processes remained normal. In another case (*C*) rounded areas of rarefaction are seen in the articular process six months after onset of symptoms.

them from other forms; yet the discogenetic type of apophyseal arthritis and that of vertebral osteophytes are distinct in spite of their common etiology. The first, hypertrophic,[17] deforming,[19] or marginal[21] spondylitis, is essentially an osteitis related to callus formation; the second, hypertrophic spondylarthritis, corresponds to the hypertrophic arthritis of other joints. They may coexist, but they differ in nature. Any mechanical strain may affect either the vertebral bodies or the

apophyseal cartilage,[13] or both. This depends on the type of traumatism as well as on the vulnerability and the ability to react of the different tissues.

Clinical findings suggest that osteoarthritis in the apophyseal joints may be caused by chronic infection with *Endamoeba histolytica*,[17] but experimental or histologic proof is not yet available.

SECONDARY INVOLVEMENT

Infection may spread from the vertebral body into the articular process and thus involve the apophyseal joint.[13, 17] This is rare since the compact bone of the arches and their processes is less easily invaded than the cancellous vertebral body. For instance, in vertebral tuberculosis the articular processes usually remain intact even when the disease persists for many years (Fig. 7). On the other hand, primary tuberculosis of cervical apophyseal joints may spread into the bone.[12] The joints may become involved when osteomyelitis localizes in the neural arch.[23] Primary osteomyelitis of articular processes without involvement of other parts of the neural arch was reported very recently.[20]

TRAUMA

Fractures of the articular processes may be combined with fractures or compression of the vertebral bodies,[1] but they are rare as independent injuries.[1, 17] Supernumerary ossicles, separated by cartilage from the main part of the articular process, may be dislodged by trauma.[1, 16, 17] Gaps in the isthmus may be widened by postural and traumatic factors, which is well known to result in spondylolisthesis.[2] The subjacent apophyseal joint may then be exposed to increased static stress[13] and will respond to it by hypertrophic arthritis. Any other abnormal position of vertebrae may lead to similar reactions.

CLINICAL RELATIONS

Since the vertebral column is composed of many bones with numerous interacting joints, none of which is easily accessible to inspection and palpation, the clinical diagnosis of vertebral disease is based on combinations of uncharacteristic findings: pain, local and radiating; diminished mobility; and abnormal posture. Except in the cervical section, the apophyseal joints are covered by thick layers of muscles and cutis; their inflammation cannot be recognized by the presence of swelling or redness; the pain it elicits is difficult to localize; and diminished mobility, if it becomes evident at all, may be accounted for by lesions of other vertebral parts. Radicular pain may be caused by any morbid process that encroaches upon the neural foramen. Thus, we cannot expect to find pathognomonic signs and symptoms.

Like arthritis of other joints, apophyseal arthritis (spondylarthritis) is associated with local pain during active phases.[12, 14, 17] When the inflammation is arrested, or when bony ankylosis prevents further irrita-

tion, local pain usually subsides. This is quite evident in rhizomelic spondylosis. The pain is due, at least in part, to muscle tension over the involved joint. When numerous apophyseal joints are affected, a large section of the back shows this muscular guarding and the back is then held stiff constantly, even during rest at night. This is probably responsible for the fact that ankylosis takes place later in the position of extension, such as in poker back. No other direct influence of spondylarthritis upon the position of the spine can be found. Pressure upon nerve roots may be caused by swollen joint capsules, by exostoses

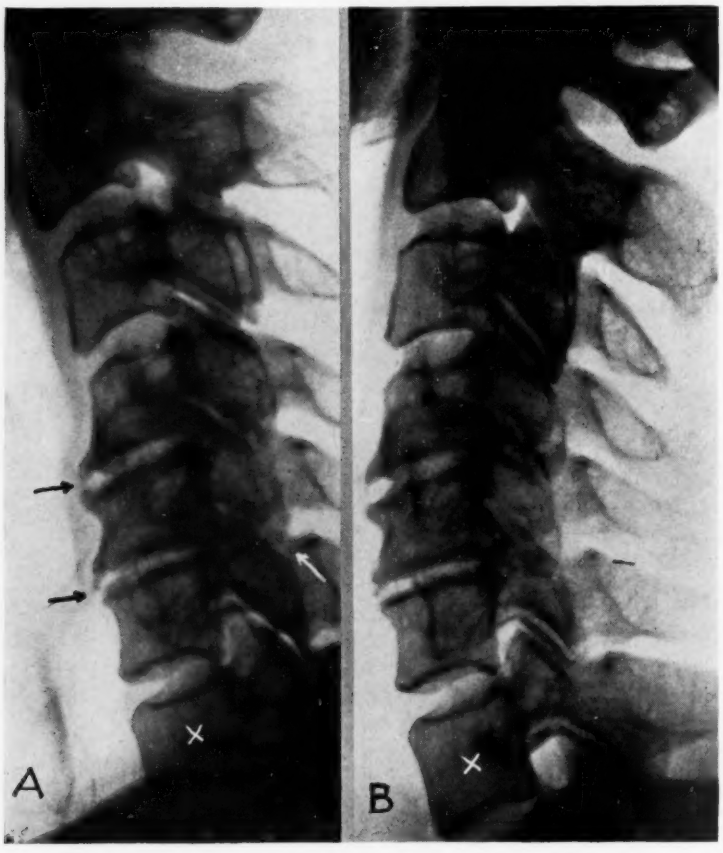

Fig. 8 *A* and *B*.—Mobility of cervical spine in two cases with thinning of fourth and fifth intervertebral disks. Extreme flexion and extension. In the first patient (*A* and *B*) the apophyseal joint spaces at the level of the flattened disk are narrow and the facets are irregularly bounded (discogenetic spondylarthritis); the segments involved are almost immovable.

at the articular processes, or by calcification of periarticular tissues;[17] wherefore signs and symptoms of radicular neuritis may occur at various stages of the arthritic process and persist after the inflammation has subsided.

The question of normal and pathologic mobility of the column cannot be discussed here, being so involved as to necessitate a separate report.[25] It may be stated that mobility is almost invariably diminished in sections which contain a diseased apophyseal joint; whereas, many other

vertebral lesions may and do fail to impair vertebral movements. For example, in segments with thinned disks flexibility usually remains normal as long as the apophyseal joints at this level are not affected (Fig. 8).

Backache, stiffness, and radicular pain are caused by certain lesions of the spine more frequently than has been appreciated in the past; this, however, has perhaps been overemphasized in recent reports, not excluding my own. It has to be borne in mind that extensive lesions of the vertebral column may fail to cause any clinical manifestations.[17] Certainly pain in the back and limbs may occur, recur, or persist in the absence of any vertebral anomaly; yet growing experience seems to show

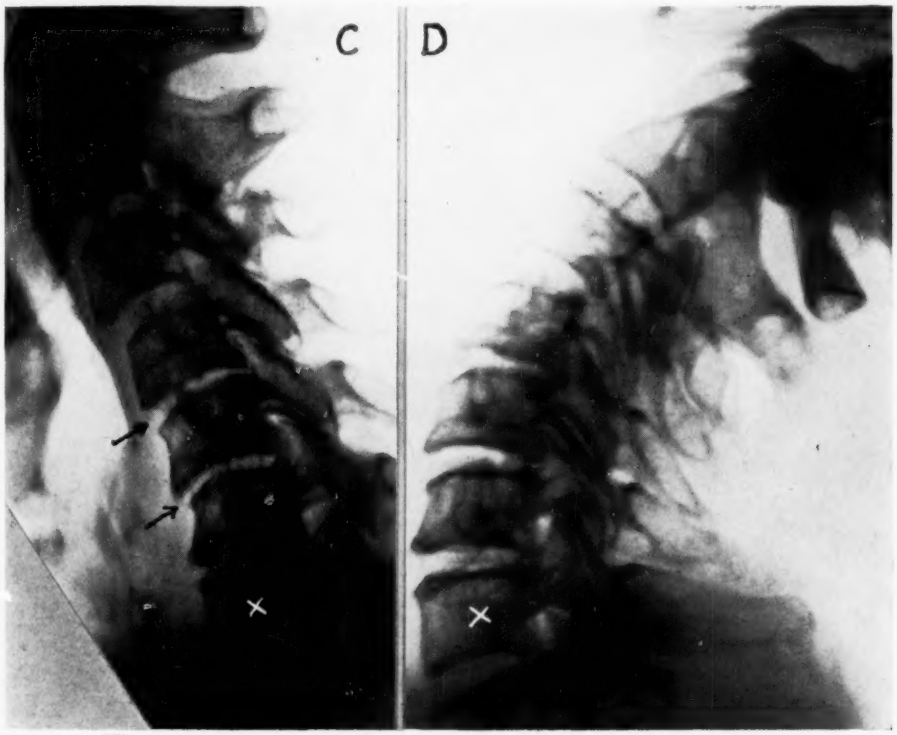

Fig. 8 *C* and *D*.—In the second patient (*C* and *D*) the apophyseal joints are not involved, and mobility is normal in spite of the thinned disks. The pictures are so taken and reproduced that the vertebra marked by *x* keeps the same position during the movements.

that, when clinical symptoms coexist with a demonstrable vertebral lesion, the nature and severity of the clinical manifestations depend to an appreciable degree upon the involvement of the apophyseal joints.[17] Local pain or tenderness of a vertebral segment, associated with rigidity of the section involved, usually means that one or several of the apophyseal joints at this level are involved either primarily or secondarily.

CONCLUSIONS

The apophyseal joints may be involved by the various forms, phases, and combinations of arthritis in the same manner as the small joints of

the hand or foot. The roentgenologic and clinical findings are those of arthritis. Atrophic (rheumatoid) arthritis is always a primary lesion; hypertrophic (osteo-) arthritis may be associated with, or induced by, other vertebral anomalies, especially thinning of intervertebral disks. Both forms are distinct from the so-called arthritis of the spine which consists essentially in exostoses at the edges of the vertebral bodies. The conception of arthritis, pertaining to lesions of diarthrodial joints, does not apply to the disk synchondrosis either anatomically or clinically; the reactions at the edges of the vertebral bodies are osteitic, but not arthritic. It is in the apophyseal joints that arthritis of the spine, or spondylarthritis, is localized. The clinical signs and symptoms are discussed briefly.

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Editorials

Nutritional Disturbances in Surgical Practice

UNTIL relatively recent times many surgeons regarded metabolic and nutritional disturbances as matters far removed from their province and of limited practical significance in the management of surgical disorders. The changing trend of the times is apparent in the character of numerous articles which have appeared in this and other journals; it is now generally known that a number of common abdominal ailments are not infrequently attended by deficiency states which have a profound influence on the course of the disease and upon the surgical risk. The occasional development of pellagra in cases of long-standing pyloric obstruction and the relatively frequent occurrence of hypoproteinemia and nutritional edema in cases of disturbances in the continuity of the gastrointestinal tract may be cited as illustrative of this fact.

Disease processes affecting the small intestine offer even more of a hazard in this respect; here multiple deficiency symptoms are, as a rule, apparent and the nutritional disorders may, in fact, overshadow the primary disease. The elimination of the absorptive function of considerable portions of the small intestine by inflammatory lesions, by resection, or by short-circuiting operations of various types is capable of producing every grade and type of avitaminosis and nutritional disorder. Mackie and Eddy[1] have recently published a report of a patient with regional ileitis who at various times gave evidence of scurvy, tetany, peripheral neuritis, and hypoprothrombinemia, the latter being due to vitamin K deficiency; in this individual the concentrations of carotene and vitamin A in the blood were also greatly reduced. In this same connection one recalls the curious macrocytic hyperchromic type of anemia associated with intestinal strictures which may well be due to failure of the absorption of the antipernicious anemia principles. Patients suffering from chronic intestinal disorders or even from chronic pancreatic insufficiency with steatorrhea may suffer from the more or less complete clinical syndrome of sprue, long noted for the number and variety of metabolic disturbances associated with it. The fundamental defect in each instance is, of course, failure of normal absorption in the small intestine.

For exactly the same reason, gastrojejunocolic fistulas may also be responsible for a variety of deficiency syndromes, especially if they are of large caliber and of long duration. In one selected group of twelve

such cases in which the patients died after operation, nutritional edema was encountered seven times; tetany, glossitis, and pellagra each three times; and a hemorrhagic diathesis, caused by failure of absorption of vitamin K, four times.[2] Fatty metamorphosis of the liver was a feature in eight of these cases, a fact which is of particular interest when one recalls the rather constant finding of a fatty liver in cases of fatal pellagra. Whether the changes in the liver are due to deficiencies in the absorption of choline and its derivatives, or whether defective utilization of nicotinic acid may play a role cannot be stated with certainty. The added surgical risk imposed by a hepatic lesion of this type and by the actual or latent prothrombin deficiency need not be emphasized. The cases cited above, of course, are extreme examples, but they do indicate the necessity of considering actual or potential nutritional disturbances in the treatment of patients with intestinal lesions.

The so-called subclinical vitamin deficiencies which may be present in certain affections of the abdomen requiring surgical treatment are not sufficiently well recognized to warrant detailed consideration at present, although they are doubtless of clinical importance. It may be said, however, that many individuals, because of long illness and a limited diet, are dangerously close to a "deficiency level" in respect to one or more vitamins. The added insult of an anesthetic and a surgical procedure, and the further reduction in food taken during the postoperative period, may precipitate a dangerous avitaminosis. This is particularly likely in respect to the "koagulations vitamin" which is stored only in small quantities and for which a critical level of deficiency is so easily attained. It is less true of the antineuritic vitamin, the body stores of which may be exhausted only after somewhat longer period of time.

Without succumbing to the importunities of those who have vitamin products to sell or without becoming unduly conscious of minor variations in the concentration of certain vitamins in the blood and urine, the surgeon can do much to advance the knowledge of deficiency states and at the same time do his patient a great service by keeping watch for the early signs of nutritional disturbances and treating them adequately. They may not be encountered frequently, but even their rare occurrence is of the greatest surgical significance.

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Suction Drainage in the Management of Intestinal Obstruction

THE REMOVAL of material by means of suction from the gastrointestinal tract in acute intestinal obstruction has become so widespread in its application that it is frequently referred to as a form of treatment for this condition, rather than as a method for decompression of distended intestine. To those responsible for the introduction and popularization of suction drainage, the procedure has been considered a means of effecting decompression of the bowel and not specifically a method of treatment of intestinal obstruction. Wangensteen and his associates have clearly stated the limitations as well as the advantages of suction drainage applied to the therapy of intestinal obstruction and have emphasized the importance of control of distention in treatment. That it has occasionally been misapplied or badly handled by those lacking an understanding of the general problems involved, the details incident to, or the patience necessary for the application of the procedure is no fault of the procedure nor of those who have found it indispensable in the treatment of intestinal obstruction.

Distention, long recognized as a dominant diagnostic feature of uncomplicated intestinal obstruction, has not received adequate consideration as the main factor responsible for lethal pathologic changes in the patient. Much interest has been displayed concerning toxemia, dehydration, and shock as causes of death, but there has been a tendency to consider lightly the role of distention in initiating these grave phenomena. Within the past ten years there has been adequate proof from clinical as well as laboratory observations to indicate that, even in the presence of complete obstruction, toxemia or shock does not occur if distention is controlled and strangulation is not a factor. Any attempt to differentiate between operative and nonoperative methods of treating intestinal obstruction indicates a lack of understanding of the general problem. Intestinal obstruction is not a single clinical entity but a variety of problems associated under one heading because of common features; i.e., the inability of the intestine to propel its contents untrammeled throughout its entire length and the early development of distention.

The lack of appreciation of the importance of the control of distention in intestinal obstruction has contributed to the high mortality of this condition. Removal of intestinal content by suction drainage is but a simple and efficient means of overcoming one very basic factor in intestinal obstruction. The level at which suction is exerted depends on the needs of the patient. The majority of cases may be decompressed by means of a catheter placed into the duodenum. The nearer the obstruction suction is exerted, the more efficient decompression is likely to be. Suction exerted just above the obstructed area decompresses the bowel as efficiently as enterostomy performed at the same point and has the same advantage with regard to feeding the patient. The mortality and

morbidity ascribable to intestinal intubation is decidedly less than in the case of enterostomy, and the method is more certain of accomplishing results.

Treves (1884) condemned the use of enterostomy on the basis that it did not relieve the obstruction. More modern writers have expressed the same viewpoint, but it ought to be emphasized that enterostomy, like suction drainage, is but a means of relieving distention. In adynamic ileus enterostomy is more likely to increase the ileus than diminish it. Enterostomy for small bowel distention has become a rare procedure, due chiefly to the realization that distention may be controlled as well by suction drainage and with less danger to the patient.

Control of distention is but one phase of the management of intestinal obstruction. The control of dehydration by the administration of fluids and salt is not considered a method of treatment in intestinal obstruction, yet it is quite an essential part of the problem of therapy, as is blood transfusion. Removal of an obstructing lesion is of major importance but should be done after the patient has been prepared for operation. Suction drainage applied to whatever level of the intestinal tract necessary to accomplish results is the most dependable and safest procedure available for the control of distention. The fact that in many cases adequate decompression suffices to relieve the obstruction does not alter the fact that actually suction drainage is but a means of controlling distention. As such it plays an indispensable part in the program of management of intestinal obstruction.

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The Clinical Relationship of Pancreatic Disease to Fatty Infiltration of the Liver

THE ESTABLISHMENT of fatty infiltration of the liver and pancreatic disease (fibrosis and necrosis) as a clinical entity is another of the innumerable examples of successful application of experimental data to the better understanding of disease in the human being. For the most part, the recognition of the disease in the human being was dependent upon the experiments of Fisher[1] and Allan and associates[2] (1924), who demonstrated that pancreatectomy in dogs led to death of the animal in two to eight months with fatty infiltration of the liver, in spite of the administration of insulin, but that death and fatty infiltration of the liver could be prevented by feeding raw pancreas. Hershey and associates[3] noted that the animals could also be saved by feeding lecithin and choline. One of the most important contributions made to the subject was the discovery by Dragstedt and associates[4] that an alcoholic extract of pancreas, named lipocaic by them, would prevent or cure fatty infiltration of the liver induced by pancreatectomy.

Pathologists are aware of the fact that fatty infiltration of the liver (without concomitant pancreatic disease) is a very common lesion, but that the exact mechanism of its development is unknown, except in the instance of the lesion herein discussed, which is a rather uncommon disease. In general, it is agreed that fat is deposited in the liver subsequent to certain types of hepatic damage. However, in the pancreatic-hepatic syndrome under discussion we have no evidence of the production of hepatitis by the pancreatic disease; it would appear more reasonable to explain the fatty deposit in the liver in this instance on the assumption that in certain types of pancreatic disease an important substance (named lipocaic by Dragstedt) which is necessary in fat metabolism is no longer produced by the pancreas.

Much credit is due Snell and Comfort[5] for establishing the importance of the pancreatic disease to the fatty infiltration of the liver in adults. In analyzing six cases reported in the literature and one I encountered, it is apparent that numerous types of processes may be the primary lesion responsible for the pancreatic damage. In two of the three cases reported by Snell and Comfort, pancreatic lithiasis appears to have been the major etiological factor. In the case I encountered, gall bladder disease (cholelithiasis) appears to have been the initial lesion, producing a pancreatitis, which in turn gave rise to the fatty change in the liver. Gall bladder disease is present in two or three of the other cases available for study, but it is difficult to determine whether this was the direct cause of the pancreatic lesion. It is well known that gall bladder disease is present in 80 to 90 per cent of patients with acute pancreatitis. Even though it is obvious that fatty infiltration of the liver is not commonly associated with this type of pancreatitis, it is my opinion that, after a large series of patients with pancreatic-hepatic disease are studied, gall bladder disease will stand out as one of the most important etiological factors in adults. The mere fact that fatty infiltration of the liver is rarely encountered in the acute edematous and hemorrhagic types of pancreatitis does not eliminate these well-known types of pancreatitis from the pathogenesis in the pancreatic-hepatic syndrome, since it takes weeks or months for the fatty infiltration in the liver to develop.

The manifestations of the so-called pancreatic-hepatic syndrome are dramatic, although a few are insidious and obscure. Weakness and malaise are perhaps the earliest symptoms; mild epigastric pain and distention are common. Nausea and vomiting may be complained of. Steatorrhea is usually present but not always. Absence of pancreatic enzymes in the duodenal secretions is very helpful in establishing the diagnosis, but probably not a necessary finding. At least in the advanced cases, one of the most constant findings will be enlargement of the liver, incident to the fatty infiltration in the liver. Diabetes of a peculiar type may be present. With the information available at the present time, it

appears that pancreatic disease (fibrosis and necrosis) is a prerequisite. Rosenberg[6] and Snell and Comfort[5] have demonstrated the efficacy of lipocaic in treating the disease.

Fatty infiltration of the liver associated with pancreatic disease of a fibrotic type is well known to pediatricians and quite common; it is known as congenital pancreatic steatorrhea. In this group of cases congenital anomalies, such as absence or atresia of pancreatic ducts, appear to be the most important of the etiological factors. So far as could be determined by my perusal of the literature, no one has suggested that this disease and the fatty liver secondary to pancreatic disease in adults are related. However, the clinical manifestations are identical; the only difference of significance appears to lie in the etiological factors. Although pancreatic lithiasis and gall bladder disease are the most obvious factors in the production of the pancreatic disease in adults, it is very likely that congenital anomalies, such as stenosis of ducts, may finally result in the production of enough pancreatic damage to give rise to the disease later in life. For these reasons it appears justifiable to conclude that congenital pancreatic steatorrhea and the pancreatic-hepatic syndrome (fatty infiltration of the liver and pancreatic fibrosis) of adults are the same disease. Because of growth demands made by the child's body, there may be more nutritional dysfunction including vitamin deficiency in the disease in childhood; however, the major points of difference are the etiological factor and the age of the patient.

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Recent Advances in Surgery

CONDUCTED BY ALFRED BLALOCK, M.D.

LOBECTOMY FOR BRONCHIECTASIS

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THE extirpation of the diseased portion of the lung as a treatment for bronchiectasis was considered as early as 1881, when Gluck[1] and others performed animal experimentations with lobectomy. In 1901 Heidenhain[2] was credited with a successful case in man. A quarter of a century later, however, the feasibility of radical surgery for bronchiectasis was still in doubt, both because of high operative mortality and the failure to achieve entirely satisfactory clinical results in surviving patients.

In 1932, Graham, Singer, and Ballon[3] collected data concerning 212 cases of bronchiectasis treated by lobectomy. The operative mortality for the entire group was 34 per cent and only 47 per cent of the survivors attained complete symptomatic relief. In the larger and more representative series the operative mortality approached 50 per cent. It is understandable why considerable courage was necessary on the part of both the patient and the surgeon when lobectomy was undertaken a few years ago.

The almost incredible improvements in the surgical treatment of bronchiectasis which have occurred in the past decade are best illustrated by including samples of recent statistics on lobectomy reported by various surgeons throughout the world. It is noteworthy that Sauerbruch, Graham, and Churchill's cases are included in the statistics collected in 1932 and it is now possible to cite the results of the same surgeons eight years later.

In England Edwards[4] has reported 166 cases of lobectomy with a mortality rate of 12 per cent. Only 2 deaths occurred in his last 54 cases. Sauerbruch,[5] of Germany, reports a 12 per cent mortality in 58 cases. At the Norwegian State Hospital, Oslo, Holst[6] has performed 12 lobectomies with 1 death. This fatality occurred in a case of bilateral bronchiectasis. The patient survived the first lobectomy, but died after the operation on the other side. In this country Churchill[7] has reported 84 cases with a mortality rate of 4.7 per cent. Sixty-six instances of unilateral lobectomy with only 1 death are included in his group. Graham,[8] O'Brien,[9] Lindskog,[10] and others have reported series of cases with mortality rates of approximately 5 per cent. It is safe to conclude, therefore, that in competent hands an operative mortality

of less than 10 per cent may be anticipated in uncomplicated cases of bronchiectasis subjected to lobectomy. It is equally important to record that in the great majority of the reported cases clinical cures have been accomplished by the operation.

That the increasingly successful application of surgical therapy is not solely attributable to technical advances becomes apparent when it is realized that, in spite of the uniformly good results from modern lobectomy, operative technique is far from standardized at the present time. It is desirable, therefore, to enumerate certain other factors which have made the present respectable status of the operation possible.

APPLICATION OF FUNDAMENTAL PHYSIOLOGIC PRINCIPLES

The hazards of opening the free pleura were appreciated by the pioneers of thoracic surgery and for many years constituted the greatest obstacle to intrathoracic operations. In 1904, Sauerbruch[11] introduced the negative pressure chamber. This was later modified by Meyer[12] in the form of a positive pressure chamber within the negative pressure chamber which could be used when necessary. The principles of these inventions to prevent the dangers of open pneumothorax were sound, but their practical application was clumsy and difficult.

Meltzer and Auer[13] in 1909 introduced intratracheal anesthesia. Its use, however, was limited and it was not until surgical opportunities of World War I necessitated extensive thoracic operations that intratracheal anesthesia was widely employed. During this same period, certain emergencies stimulated research in the physiology of the chest which resulted in the establishment of basic principles which influenced the whole future of thoracic surgery. Among the most important of these, from the surgical standpoint, was the work of Graham and Bell[14] on the effect of altered intrapleural pressures in intrathoracic operations and the relationships of open pneumothorax and vital capacity. The general appreciation and acceptance of the principles elucidated during this period make an extensive discussion of the physiology of the chest unnecessary. It is important, however, to realize that modern thoracic surgery may be dated properly from the time of the first world war, and its rapid progress has in a large measure been dependent on the fundamental surgical physiology learned at that time. Once the effects of open thoracotomy on the circulation and respiration were understood and an anesthesia technique perfected to control intrapulmonary pressure in a practical way, subsequent progress in thoracic surgery was rapid.

IMPROVEMENTS IN DIAGNOSTIC STUDY OF THE BRONCHIAL TREE

Although Roentgen's[15] discovery of the x-ray in 1895 marks the introduction of the most important refinement in the diagnosis of chest

disease, it was not until twenty-seven years later that Sicard and Forestier[16] introduced lipiodol and furnished an accurate method for localizing bronchiectasis in the living patient.

As many of the improvements in the results of lobectomy are attributable to expert interpretation of lipiodol bronchograms and a better understanding of the surgical anatomy of the tracheobronchial tree, it is important to direct attention to certain facts concerning the localization of bronchiectasis which in the past have not been appreciated.

The conception that bronchiectasis is primarily a disease of the lower lobes is undoubtedly responsible for many unsatisfactory results of lobectomies for bronchiectasis. The common combination of involvement of the lingular division of the left upper lobe and the right middle lobe in association with bronchiectasis of the corresponding lower lobe has been emphasized recently by several authors. In 49 cases subjected to lower lobe lobectomy by Churchill,[17] 33 per cent of the patients had involvement of either the lingula of the left upper lobe or of the right middle lobe. O'Brien[9] cites 11 cases of unilateral bronchiectasis, 4 of which showed bronchial dilatations in the left lingular bronchial division or in the right middle lobe. In 47 cases of lower lobe bronchiectasis studied by Myers and Blades,[18] 57 per cent of the patients with left lower lobe bronchiectasis also had involvement of the lingula of the left upper lobe. Right middle lobe bronchiectasis was present in 59 per cent of the patients who had diseased right lower lobes. The combination of left lower lobe bronchiectasis and bronchiectasis of the lingula of the left upper lobe is so frequent that Churchill and Belsey[19] consider segmental pneumonectomy a more appropriate descriptive term than lobectomy when left-sided lesions are encountered. In their excellent article they describe the surgical anatomy of the lingula of the left upper lobe and further emphasize the frequency of bilobar involvement. Sauerbruch[20] had noted this frequent distribution of bronchiectasis in a study of autopsy specimens before lipiodol bronchograms were available. Unfortunately, his observations did not receive the attention they deserved. Neither technical difficulties nor operative risks are increased by removing the lingula of the left upper lobe or the right middle lobe when the corresponding lower lobe is resected. Failure to excise all of the diseased tissue, of course, will result in unsatisfactory clinical results.

Various methods have been suggested for the administration of lipiodol, but it is of no great importance which technique is employed so long as each segment of the lung is visualized and the bronchograms are interpreted properly. Goldman and Adams[21] recently reported a method of endobronchial probing through a bronchoscope by which each bronchial segment may be visualized separately. The introduction of the oil by tracheal puncture or by means of a nasal catheter has been advocated also. We are of the opinion, however, that the ad-

ministration of lipiodol by the simple aspiration method described by Singer[22] is preferable to the more elaborate and time-consuming techniques.

Lipiodol bronchograms which are prepared in the frontal projection will not furnish satisfactory delineation of the lingular bronchus on the left or the middle lobe on the right. It is necessary, therefore, to combine frontal and lateral projections with independent filling of the bronchi of each lung, made at intervals long enough apart to allow evacuation of the oil from the lung first visualized, or to employ oblique projections of each side. Bronchograms prepared in the

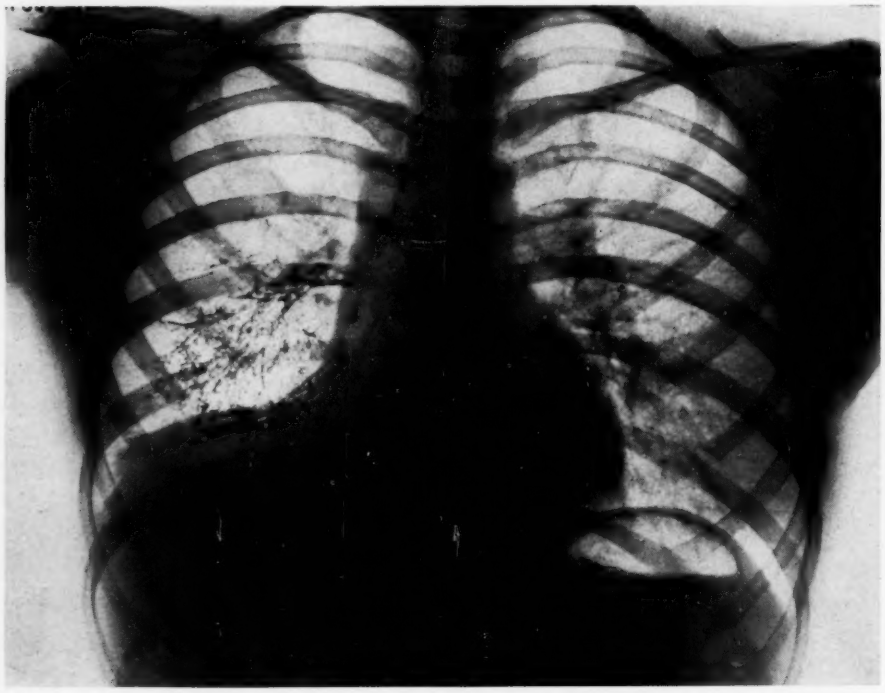

Fig. 1.—Lipiodol bronchogram taken in left anterior oblique projection (right posterior oblique). Note clear delineation of right middle lobe. It was necessary to remove both the lower and middle lobes in this case.

oblique position offer two advantages: (1) Both lungs may be filled at a single sitting without difficulty in distinguishing each bronchial segment and secondary division. (2) Only two x-ray films need to be exposed, as contrasted to twice that number when a combination of frontal and lateral projections are utilized. A bronchogram taken in the right anterior oblique position (left posterior oblique) is employed for the visualization of the left bronchial tree. The left anterior oblique or right posterior oblique is necessary to demonstrate the right bronchial segment (Figs. 1 and 2).

Instances of single lobe involvement other than the lower lobe are not uncommon. Whiteside[23] has reported a successful middle lobe

lobectomy for bronchiectasis, and in our own series we have had 2 cases of bronchiectasis confined to the middle lobe treated successfully by surgical extirpation. Churchill and Belsey[19] have reported disease of the lingular division of the left upper lobe alone for which they have performed lingulectomy. Regardless of the location of the dilated bronchi, either of the two methods for preparing bronchograms which have been illustrated is satisfactory for preoperative localization of bronchial dilatations.

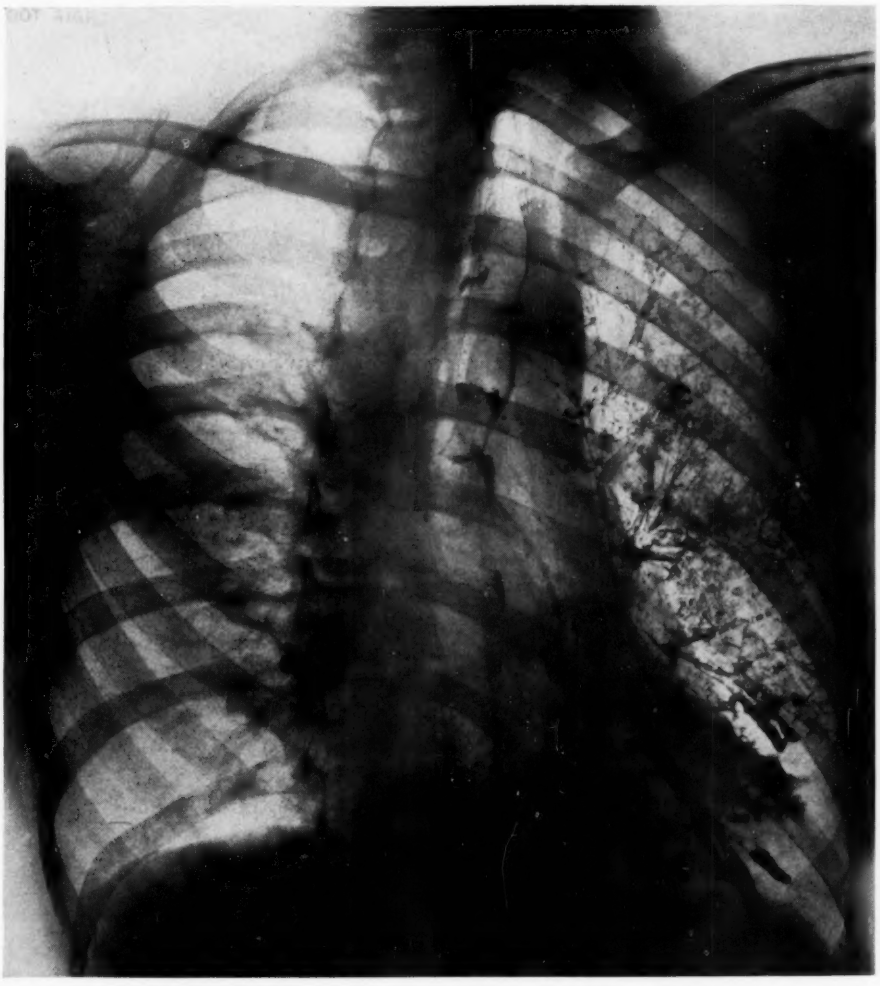

Fig. 2.—Right anterior oblique (left posterior oblique) bronchogram demonstrating bronchiectasis of left lower lobe and lingula of left upper lobe.

JUSTIFICATIONS FOR RECOMMENDING LOBECTOMY

The studies of Findlay and Graham[24] in children, and similar observations of Roles and Todd[25] in adults, have established the grave prognosis associated with bronchiectasis. Their work indicates that the disease is progressive and eventually is fatal in the great proportion of cases.

Even if this were not the case, relief of mental and physical handicaps endured by individuals who regularly cough up foul sputum should justify any procedure which is not accompanied by an excessively high operative mortality. The failure of medical treatment except as palliative, the questionable results obtained with pneumothorax, thoracoplasty, and other forms of collapse therapy in bronchiectasis establish lobectomy as the only completely satisfactory method of treatment. It is, therefore, not so important to define the indications for lobectomy, but rather to know which patients cannot be treated safely by radical surgical intervention.

CONTRAINDICATIONS TO LOBECTOMY

The age of the patient must be considered, and at the present time patients past middle age are not considered suitable risks for lobectomy. The upper age limit will vary in the individual case, depending on the general condition and the extent of the disease. Children tolerate intrathoracic operations particularly well, and for obvious reasons it is desirable to eradicate the disease before irreparable physical and psychological damage is done.

The presence of other serious conditions, particularly cardiovascular disease, of course, will preclude the possibility of lobectomy. The risk of operation is increased if it is attempted in the presence of acute infections of the lung, and, unless serious hemoptysis forces emergency measures, lobectomy should be delayed until the patient is afebrile.

The extent and distribution of the disease must be considered before lobectomy is recommended. Successful trilobe lobectomy has been reported by Overholt.[26] Graham[27] has removed successfully the right middle, right lower and, eighteen months later, the left lower and lingula of the left upper lobe in a boy 16 years of age. Successful bilateral lobectomies have been reported by Lewis,[28] Churchill,[29] and others. Total pneumonectomy for unilateral universal bronchiectasis is now so common that it requires no particular comment. It would seem, therefore, that the amount of lung tissue which may be extirpated safely must be determined by a consideration of vital capacity, the patient's age, and other individual factors. In several of my own cases of bilateral bronchiectasis removal of the bronchiectatic portion of lung on one side has been followed by so much improvement that the patients have decided to postpone operation on the other lung. In every instance the more severely diseased lung was operated upon first. Whether these patients will continue to be free of symptoms cannot be determined until more time has elapsed. Our experiences suggest, however, that, even in the presence of extensive bilateral disease, extirpation of the principal site of the bronchiectatic dilatations is justifiable.

Edwards[4] in a recent article has summarized his indications for lobectomy as follows: "Patients between the ages of 4 and 40 (and

exceptionally older) with bronchiectasis which is reasonably localized and infected, and in whom there are no serious general contraindications, should be considered as candidates for radical excision of the portion of the lung affected.''

PREOPERATIVE PREPARATION FOR LOBECTOMY

The preoperative program is designed to decrease at least temporarily the amount of pus in the bronchiectatic dilatations. The measures employed for this purpose are similar in various thoracic clinics, and it is impossible to know whom to credit for the originality of various details in the preoperative and postoperative management. For convenience, the methods which I have followed at the Barnes Hospital Chest Service in association with E. A. Graham will be described.

The association of chronic nasal sinus disease with bronchorrhea was first noted by Thomson in 1914.[30] Practical application of this observation was later suggested by Graham and Singer,[31] who advocated adequate treatment of infected nasal sinuses in all cases of bronchiectasis and found that there was usually an improvement in the patient's general condition and diminution in the amount of sputum. Therefore, in patients who are considered suitable subjects for lobectomy the first precaution is adequate treatment of infections of this nature.

The second important preliminary to lobectomy is the institution of postural drainage supplemented by bronchoscopic aspirations. The value of bronchoscopy cannot be overemphasized. Not only is diagnostic information concerning possible foreign body, neoplasm, and localization of the lesion essential, but the temporary improvement following bronchoscopic aspiration of pus will often convert the poor risk patient into a reasonably good candidate for a lobectomy. However, when improvement follows a series of bronchoscopic aspirations, it must be remembered that no proved case of bronchiectasis has been cured permanently by this method. Patients should be informed of this fact and made to realize that the risk of lobectomy is proportionate to the amount of active infection in the lungs, and that the optimum time for operation is when symptoms are minimal. The number of bronchoscopic aspirations which will be required depends largely upon the amount of purulent secretion and the patient's general condition.

Compression of the lung by artificial pneumothorax preliminary to lobectomy has been advocated and employed routinely in many clinics. It is doubtful, however, that effectual evacuation of pus-containing bronchi can be accomplished by any form of collapse therapy, and, although the danger is not great, accidental puncture of infected lung during the introduction of air may result in serious complications. The benefits of pneumothorax in causing gradual accommodation to altered intrapleural pressures encountered during the performance of the operation is of doubtful value. It is probable, therefore, that artificial

pneumothorax in the future may be reserved for cases subjected to pleural poudrage, a procedure which will be included in the discussion of operative technique.

ANESTHESIA

The ideal anesthetic for intrathoracic operations should furnish first, and most important, a practical means of controlling intrapulmonic pressure; second, facilities for aspirating the respiratory passages during the course of the operation; and, third, rapid return to consciousness on the part of the patient to prevent abolishment of the cough reflex for an extended period of time. Intratracheal administration of the anesthetic insures a stable intrapulmonary pressure and a means for aspirating the trachea. Cyclopropane gas provides the rapidly reversible type of anesthesia.

The introduction of cyclopropane by Lucas and Henderson[32] and the work of Stiles and co-workers,[33] which established it as a reliable and safe anesthetic agent, constitute one of the real advances in thoracic surgery. This gas answers practically all of the anesthetic problems peculiar to thoracic surgery. In addition to the advantages which have been enumerated, the ability to administer a high percentage of oxygen, or, if necessary, helium, with cyclopropane (60 to 70 per cent oxygen) permits a satisfactory depth of anesthesia and eliminates the anoxemic states which in the past were so common when nitrous oxide or nitrous oxide-ether anesthesia was employed. The only disadvantage of cyclopropane is that the gas is explosive, and the possible advantage of diathermy or the cautery must be sacrificed when it is used.

There have been many improvements and modifications of the original Meltzer-Auer technique of intratracheal anesthesia, which consisted of alternate insufflation of the lungs under hyperpressure. The most objectionable feature of this method was the strong positive pressure which was employed and the virtual standstill of the lungs between insufflations. Defrise[34] has advocated what he terms a spiropulsator which permits rhythmical increase and decrease of intrabronchial pressure during anesthesia, and recently Crafoord[35] has introduced an anesthesia machine which provides for automatized controlled respiration. These and other inventions have improved the methods of delivering the anesthetic agent and have increased the already wide margin of safety in intratracheal anesthesia.

Lewis,[36] Magill,[37] and others have reported the successful use of spinal analgesia in lobectomy cases. Pieri[38] has employed peridural anesthesia and Burnett[39] has recommended local field block. Although it is admitted that patients with sufficiently large vital capacities will tolerate open thoracotomy without the protection of controlled intrapulmonic pressure by intratracheal anesthesia, the deliberate choice of any other method in intrathoracic operations is difficult to understand.

PRECAUTIONS IN THE OPERATING ROOM

In addition to the complications of shock and hemorrhage which may occur during any major operation, the possibility of suffocation from aspiration of pus or blood must be guarded against in all intrathoracic procedures. This is a particularly potent danger in cases of bronchiectasis, where it is almost impossible to avoid squeezing pus out from the bronchial dilatations when the lung is manipulated during the course of the operation. In the majority of instances aspiration through the intratracheal catheter through which the anesthetic agent is administered will keep the airways open. There are occasions, however, when sudden flooding of the tracheobronchial tree by pus or blood will necessitate emergency bronchoscopy. In a few cases where almost constant flooding of the tracheobronchial tree has occurred, we have administered the anesthetic through the bronchoscope, aspirating as often as necessary until the operation was completed. A few minutes' delay in cleaning out the trachea and bronchi may result in the death of the patient. It is necessary, therefore, to have immediately available in the operating room equipment for bronchoscopic aspiration and a capable bronchoscopist. By far the most satisfactory plan is to have a member of the operating team other than the surgeon capable of performing bronchoscopy. This arrangement will enable the surgeon to remain at the operating table and to continue with the operation without delay when the patient's respiratory embarrassment is relieved.

In our own clinic we have adopted a routine for lobectomy cases which includes bronchoscopic aspiration immediately before and after operation. The purpose of the first aspiration is to remove as much of the pus from the diseased lung as possible, the second to evacuate any spillover of blood or pus to the contralateral lung which may have occurred during the operation. It is significant that since adoption of this program about two years ago we have not had a death from postoperative pneumonia or spillover infection in cases subjected to lobectomy.

The simple expediency of being prepared for serious hemorrhage in all thoracic operations will eliminate, except in unusual instances, the danger of fatalities from this complication. Actually, severe bleeding rarely occurs during the performance of lobectomy, but when it does a few moments' delay in replacing the blood spells calamity. It is our custom, therefore, to insert a needle in an ankle vein before the operation is begun through which a continuous flow of physiologic saline or 5 per cent glucose solution may be maintained during the course of the operation (Fig. 3). Compatible citrated blood is available in the operating room and may be given through the

same apparatus whenever necessary. The few instances of severe hemorrhage which we have encountered during the performance of lobectomy have been controlled satisfactorily by this method.

TECHNIQUE OF LOBECTOMY

At the present time, it is impossible to designate the preferred technique for lobectomy, and it is hazardous to predict the method which will be in favor five or ten years from now. There is, however, an increased tendency to employ single-stage operation as contrasted to the

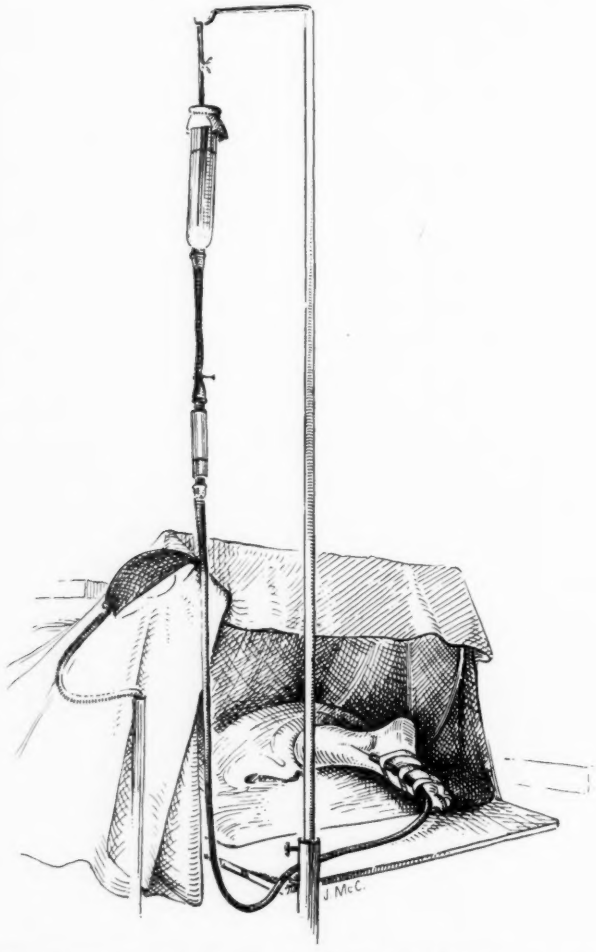

Fig. 3.—Drawing showing arrangement for the administration of intravenous fluids into an ankle vein.

situation a few years ago, when the operation was usually divided into two or more stages. Methods which involve the exteriorization of the diseased lobe which was allowed to slough away gradually have been abandoned generally in favor of clean surgical resection of the diseased portion of the lung.

The advantages of having the undiseased portion of the lung held to the chest wall by pleural adhesions have been appreciated for many years, and there have been various types of two-stage operations designed to promote protective adhesions before the lobe was removed. Sauerbruch[40] inserted paraffin wax on the parietal pleura after removal of segments of several lower ribs in an effort to produce pleural symphysis. Alexander[41] described a two-stage operation in 1933 designed for the same purpose. In the first stage three ribs, the intercostal bundles, and the parietal pleura were excised, the affected lobe was freed, and the pleura was gently wiped with gauze. The second stage was performed ten to fourteen days after the first stage. Churchill,[17] in 1937, recommended a two-stage operation which involved resecting a portion of the eighth rib and division of the adhesions over the affected

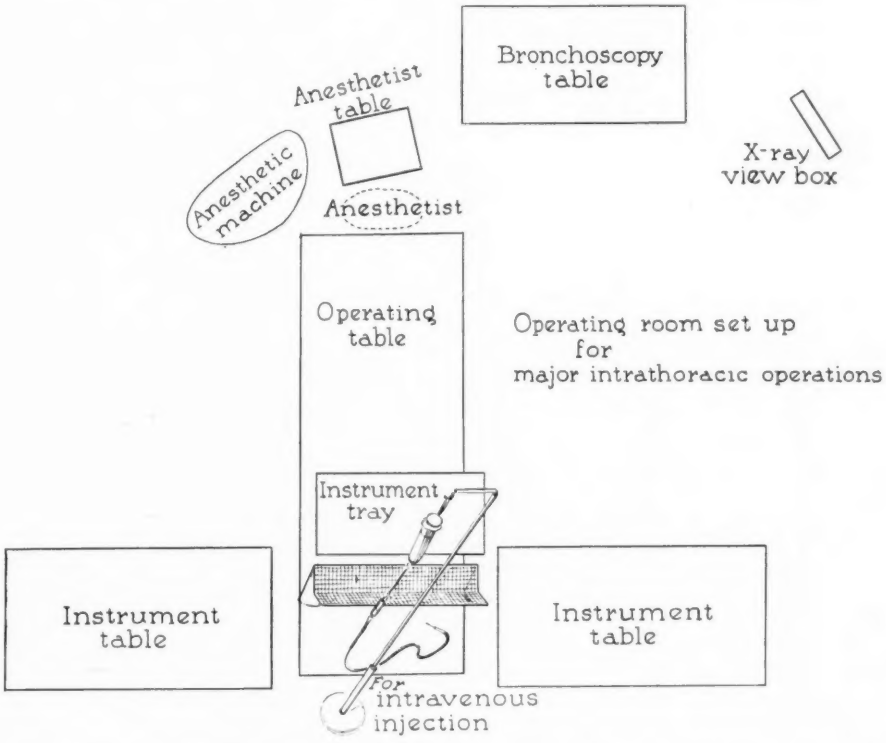

Fig. 4.—Diagrammatic sketch of operating room containing the equipment necessary for major thoracic operations.

lobe. The parietal pleura in the vicinity of the upper lobe was wiped with gauze and the chest closed without drainage. The second stage was postponed for several weeks, and in some instances for months. This delay is, in Churchill's opinion, of great importance, because the patient is given sufficient time to recover from the effects of a major operation, and, moreover, considerable time is necessary for the formation of pleural adhesions of proper density and strength. Monod and

Bonniot,[42] Churchill,[17] and others feel that the choice between a one-stage or two-stage procedure will depend upon the individual case. Included is Monod's summary of the indications for one- and two-stage lobectomy:

One-Stage Operation: (1) Obliterated pleural space. (2) Operations on children. (3) Middle lobe lobectomy. (4) Severe hemoptysis. (5) Lobar atelectasis. (6) Draining thoracotomy sinus or bronchocutaneous fistula. (7) Cutting into infected lung when freeing adhesions. (8) Bronchial stenosis.

Two-Stage Operation: (1) Adults with free pleura. (2) Febrile patients with active pneumonitis. (3) Patients treated for a prolonged period with artificial pneumothorax and not having adherent upper lobe. (4) Bilateral cases with free pleural space.

The necessity of performing intrathoracic operations in multiple stages to decrease operating time and thereby lessen the danger of shock or asphyxiation has been practically eliminated by improved anesthetic technique and proper preoperative preparation. The choice between single- and multiple-stage lobectomy will depend, therefore, upon whether or not the value of protective pleural adhesions justifies a major operation to produce them. It is entirely possible that this controversial point will never be settled, as it now seems probable that the comparatively innocuous procedure, pleural poudrage, will prove a safe and effectual method of producing pleural adhesions.

Pleural poudrage was first performed on animals by Bethune[43] in 1935. He found that magnesium silicate to which 0.5 per cent iodine had been added (BPC Talc) dusted on the pleura through a bronchoscope would create satisfactory adhesions. Gowar[44] in England has recently investigated the problem of pleural poudrage, using a wide variety of chemical irritants on the pleura. He concluded that the powder originally used by Bethune is entirely satisfactory and can be employed safely. The operation has been used by Edwards preliminary to lobectomy in 8 adults, and he feels that the effects have been beneficial in every instance. The procedure is receiving an extensive trial by those who place a large premium on protective pleural adhesions, and it is safe to predict that, in the future, pleural poudrage will supplant open thoracotomy as the first stage in two-stage lobectomy.

Interest in single-stage lobectomies was revived in 1929 by Brunn[45] who reported 6 cases with 1 death, and his experiences stimulated others to attempt operations in the free pleura without protective adhesions. The tourniquet, designed by Shenstone and Janes[46] to control the hilum of the lobe until the structures were secured by sutures, added to the popularity of the one-stage procedure, and in the majority of clinics today the technique most frequently employed is probably that of mass ligation of the hilum of the lobe with the aid of a tourniquet, performed in a single stage. The advantages of the tourniquet technique are

chiefly: (1) decreased danger of serious hemorrhage; (2) the ability to perform the operation rapidly in subjects who are poor risks; (3) avoidance of the tedious dissection through indurated, infected tissue. The disadvantages are mainly the results of mass ligation of a rather large pedicle of tissue. Fortunately, the low blood pressure in the pulmonary circulation (about 30 mm. mercury) minimizes the danger of secondary hemorrhage, and from the standpoint of reliable hemostasis individual ligation of the blood supply to the lobe is not necessary. Permanent closure of the bronchus, however, constitutes an entirely different problem, and it is in this respect that mass ligation is far from satisfactory. A leak in the bronchus immediately or soon after the operation is serious. Actually, this rarely occurs, and, when a fistula develops late in the postoperative course, the danger to the life of the patient is slight. Empyema thoracis is inevitable, however, if the bronchus does not remain closed. The importance of preventing infections of the pleura following lobectomy can best be emphasized by stating that during the past two years every death from lobectomy which has occurred in my own cases has been the result of a putrid, necrotizing empyema.

It is appropriate at this time to include a word concerning the treatment of empyemas which may complicate lobectomies. With the exception of adequate and early drainage of the pleura, we have been unable to find any effective way to check such infections. At the suggestion of E. A. Graham, blood serum from patients who had recovered from similar infections has been given intravenously and intramuscularly for the purpose of providing protective antibodies. There was no beneficial effect. Chemotherapy in the form of sulfanilamide, sulfapyridine, and lately sulfamethylthiazol has not altered the severity or duration of the infections.

The high incidence of permanent closure of the bronchus and absence of empyemas in instances of total pneumonectomy accomplished by separate ligation of each structure in the pulmonary hilum has stimulated us to apply individual ligation technique to cases of lobectomy, and in 11 consecutive cases in which this method was employed we are privileged to report that only 5 patients developed empyemas. None of the infections was of the putrid variety. Minute bronchial fistulas could be demonstrated in these same patients only by irrigating the empyema cavity with saline solution, and in all instances the fistulas closed within two weeks. These results are encouraging, but more experience with the technique is necessary before final conclusions are drawn. Certainly there will be cases in which adhesions and induration at the root of the lobe will preclude an attempt to dissect out each structure. Speed must be sacrificed if the dissection is carried out, and, when emergencies demand the rapid completion of the operation, mass ligation with a tourniquet is desirable. We feel, however, it is fair

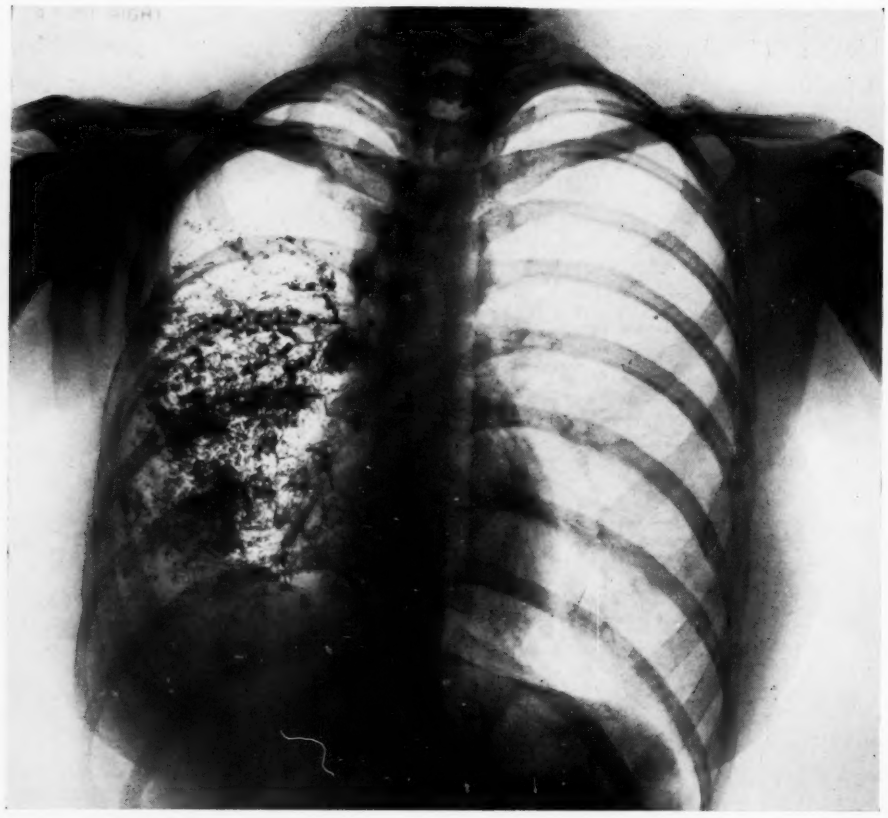

Fig. 5.—Postoperative lipiodol bronchogram after right lower lobe lobectomy by individual ligation technique. Note complete absence of residual bronchial stump. There was no postoperative empyema.

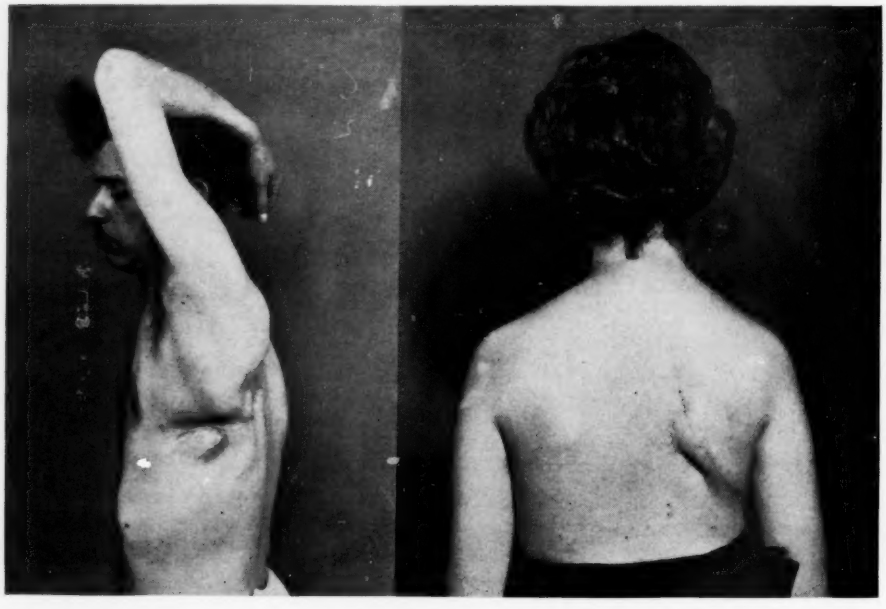

Fig. 6.—Improvements in the cosmetic result of lobectomy are noted by contrasting two patients operated upon by E. A. Graham, one (*A*) who had his operation twenty years ago, and the other (*B*) who had a lobectomy in 1938. No ribs are now removed and there is therefore no deformity of the thorax.

to assume that, when feasible the individual ligation technique for lobectomy has distinct advantages over mass ligation, by insuring better bronchial closure and reducing the incidence of postoperative empyemas (Fig. 5).

One of the most important advances in the technique of partial or complete pneumonectomy has been the perfection of methods by which it is possible to remove all or part of the lung without producing visible deformity of the chest wall. It is no longer considered necessary to resect portions of several ribs to obtain adequate exposure for intrathoracic operations, and the division of two or three ribs near their posterior attachments or the resection of one rib will, except for rare instances, furnish splendid exposure for lobectomy. Fig. 6 reveals the contrast in the appearance of the chest wall of the patient operated upon twenty years ago for lower lobe bronchiectasis and one on whom modern technique was employed.

POSTOPERATIVE CARE

The postoperative care of a patient who has been subjected to lobectomy involves attention to the same details which are important following any major operation. During the first six or eight hours after the operation, pulse and blood pressure readings must be checked frequently and, if there is any tendency toward shock, a transfusion of blood should be given. In addition to these precautions it is important that the patient be encouraged to cough as soon as he reacts from the anesthetic. Although it is not absolutely necessary, the routine use of an oxygen tent is desirable because the immediate postoperative discomfort is decreased by the constant, cool, oxygen-rich environment. The necessity for frequent change of position must be emphasized to the nursing staff. It is our custom to keep the patient on his back or with the side which has been operated upon down until all the effects of the anesthesia have disappeared. These same positions are encouraged throughout the postoperative course when the patient is sleeping, for, in case the bronchus should open suddenly, fluid might be aspirated to the contralateral lung while the patient is unconscious. The catheters which have been inserted into the chest at the time of operation should be inspected at least twice a day to be sure that they are open and functioning properly. The catheters are gradually shortened throughout the postoperative course and, in the uncomplicated case, can be withdrawn in three or four weeks. Patients are usually allowed to be out of bed within three weeks, depending, of course, upon the condition of the individual case.

SUMMARY

In a period of less than ten years the mortality rate of lobectomy for bronchiectasis has decreased from approximately 50 per cent to less than 10 per cent. In contrast to the questionable clinical results ob-

tained by the operation a few years ago, excellent results can now be anticipated when lobectomy is employed. The remarkable advances which have occurred are not dependent on refinements in operative technique or any other single factor, but have been the result of a combination of improvements in anesthesia, proper preoperative localization of the disease, and certain preoperative and postoperative precautions which have been described.

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Book Reviews

Obstetrical Practice. By Alfred C. Beck, M.D. Cloth. Ed. 2. Pp. 858, with 1,043 illustrations. Baltimore, 1939, Williams & Wilkins Co. $7.

This is a second edition of the well-known Beck text. The author states that it is designed to satisfy the requirements of the student and the young practitioner. With this in mind, the subject is presented as briefly as possible and with a dogmatic approach which is probably justified for student consumption.

The author has introduced several original and effective methods of presentation. The book is profusely illustrated, for the most part by the author's own drawings. These are mainly directed toward the illustration of mechanical problems. In particular, the mechanism of labor is presented by means of illustrations which are effective and make the usual verbal descriptions seem poor by comparison. The use of outlines of the subject material to follow will aid the undergraduate student in grasping the problem as a whole.

The expressed intention to avoid irrelevant argument is belied by an excellent and up-to-date bibliography at the end of each chapter. This will be of value to all readers.

Many of the special phases of obstetrics have been either written or reviewed by outstanding authorities in the fields. This also adds to the value of the book.

Against this may be placed a brevity of description which may be suited to the classroom but not to the graduate student. The space given to the nonconvulsive toxemias in particular is scanty. However, the valuable features outweigh this criticism and the book is an excellent one for undergraduate use.

Textbook of Surgery. By John Homans, M.D., Clinical Professor of Surgery, Harvard Medical School. Ed. 5. Pp. 1,272, with 530 illustrations. Baltimore, 1940, Charles C. Thomas, Publisher. $8.

Reviewing this book has been a pleasant privilege because it is written in such an interesting style and at the same time presents an enormous amount of information for a one-volume text. The extensive amount of medical and surgical history preceding each chapter is an attractive feature to the older group of readers, but might be considered too long by the student (already overburdened with reading assignments) unless he has no course in medical history.

The greatest criticism offered by the reviewer lies in the comparative amount of space devoted to the respective subjects. In his opinion far too much space is devoted to neurology and neurological surgery. For example, only six and one-half pages are devoted to the very important subject of shock and hemorrhage; whereas, an entire chapter of slightly less than nine pages is devoted to the pituitary gland. No doubt the author has allowed sentiment to influence him in his extensive consideration of the pituitary gland and other neurological subjects because of his respect for the late Harvey Cushing, a truly great surgeon worthy of all possible credit. But is it appropriate to allow sentiment to exert so much influence on the amount of space devoted to the various surgical subjects in a textbook?

In the preface to the fifth edition the author states that he has deliberately refrained from changing the pagination of the text, ever since the appearance of the first edition. He thereby implies that our knowledge of the various subjects in surgery, or their importance, does not change enough as the years roll by to warrant changing the amount of space devoted to these subjects. Other examples of maldistribution of space are noted. For example, the discussion on wounds is limited to six pages in the chapter on surgical technique, except for additional data scattered throughout the book in areas where they are not readily found. The reviewer is inclined to believe that the subject of wounds is sufficiently important to deserve consideration in a separate chapter. One and one-half pages are devoted to typhoid fever and only two and one-half pages to tetanus. In the discussion of tetanus no mention was found of the use of active immunization—a subject so very important in these Martian times. Surgeons in the southern climate might object to devoting only one-half page to lymphopathia venereum.

The chapters on blood vessels and lymphatics are very well done, as are also the chapters on anesthesia and amputations, which represent material added since the first edition. Surgery of tuberculosis is discussed in a splendid manner.

The chapter on intestinal obstruction is not up to the standard of the rest of the book. The reviewer would criticize the author's weak acceptance of the value of Wangensteen suction in the treatment of intestinal obstruction. Doubtful acceptance would not have been so inappropriate a few years ago when it was first introduced, but the frequent reports of such radical reductions in mortality by its use would appear to establish it as a definite aid in the treatment of intestinal obstruction. In the discussion of methods of intestinal decompression many surgeons, indeed, would object to the statement or question appearing on page 938, reading as follows: "For if they are to replace operation, how is it known that, in any case, strangulation of intestine is not present?" The authors writing on the subject of intestinal obstruction do not appear to have that much difficulty in determining the presence or absence of strangulation.

In the discussion of posterior operation for carcinoma of the rectum on page 986, a statement is made, the latter half of which reads as follows: "(Lockhart-Mummery) carries a low mortality but leaves behind such cancerous nodes as are associated with the proximal portion of the superior hemorrhoidal artery (page 969) not a very serious disadvantage." This is presumably a misprint, the word "not" being included by error. If not, the statement requires supporting data.

Remarkably few misprints or misstatements are found. For this accomplishment the author is to be congratulated. As a whole the book is splendid and will be a valuable one for use by the student or teacher.

Principles of Surgical Care: Shock, and Other Problems. By Alfred Blalock, M.D. Pp. 323, with 13 illustrations. St. Louis, 1940, The C. V. Mosby Co. $4.50.

There is probably no one so well equipped to write a monograph on shock as is Blalock, and he has lived up to expectations in presenting a book which every student and every practitioner of medicine should have. Although shock is the principal theme of the monograph, those factors which predispose to the development of shock and which, if prevented, will prevent shock are adequately discussed. A particularly important chapter as regards this point is that on anesthesia and anesthetic agents. The chapter on shock is superbly done with a complete review of the literature. The author's own fundamental investigations and a review of 246 references give a résumé on this subject which is thoroughly complete. Of

great importance in the care of patients preoperatively and postoperatively is the determination of metabolic and nutritional disturbances and their correction by the administration of fluids and electrolytes. This is well discussed from the physiologic and physiochemical aspects. Other postoperative disturbances, such as nutritional disorders, including vitamin deficiencies and endocrine deficiencies, as well as postoperative pulmonary and abdominal complications, are thoroughly considered. Throughout the book the physiologic aspect is always foremost and the rational consideration of each condition is discussed. Last, but certainly not least, one of the most valuable parts of the entire book is the very complete bibliography. Few monographs are so completely done. Because of the completeness of the work and because of the author's vast experience with the subject, this book should be in the library of every student and practitioner of medicine.

Minor Surgery. By Frederick Christopher, M.D. Ed. 4. Cloth. Pp. 990, with 639 illustrations. Philadelphia, 1940, W. B. Saunders Co. $10.

To those familiar with the previous editions of this book no recommendation is necessary, other than to say that the fourth edition is a worthy successor to its predecessors. This last edition comprises 990 pages and is abundantly illustrated with both photographs and drawings. The subjects discussed include many things which are not usually classed as minor surgery. For example a rather extensive survey of the treatment of fractures is given. As is stated in the preface, however: "The subject matter deals with those procedures which comprise numerically the bulk of all surgical procedures, the ones carried out by the general practitioner, the physician who does not have ready access to a large hospital or contact with surgical specialists, the younger surgeon, the resident surgeon and the intern." This is an eminently practical book. It will often be referred to when those more or less simple conditions, the proper care of which may have been crowded from the doctor's memory by more complicated and serious matters, are under consideration. Throughout the book emphasis has been laid on treatment and technique. The printing in small type of many paragraphs concerned with technique has made it possible to include an unusual amount of detail and certainly increases the value of the book. Included at the bottom of appropriate pages are 268 references to original articles in the recent medical literature. Practically all the newer concepts of surgical treatment have been included to bring the treatise completely up to date. These include the various methods of handling wounds, the administration of intravenous anesthetics, peritoneoscopy, vitamin therapy, water and electrolyte balance, and intermittent venous occlusion.

However specialized or however experienced the surgeon may be, he will find much in this book which will be valuable to him.

Operative Surgery. Ed. 5. By J. Shelton Horsley, M.D., and I. A. Bigger, M.D. 2 vols. Pp. 1567, with 1,391 illustrations. St. Louis, 1940, The C. V. Mosby Co. $18.

The fifth edition of Horsley and Bigger's *Operative Surgery* has been changed considerably and has been modernized to include many of the newer procedures which make the book valuable for the student and the surgeon. Such operations as ligation of the patent ductus arteriosus, extrapleural pneumothorax, and many other new ones have been included in this edition. The book is well illustrated and is well written both from the standpoint of description and from the standpoint of reasoning.

In discussing complications of operations in the sections on shock and hemorrhage, the uses of sulfanilamide and sulfapyridine are adequately described. The chapter on continuous intravenous injections is particularly well done, as could be easily imagined because of the interest which the senior author has had in this subject. In it are included the importance of preventing hyperproteinemia and also the newer use of alcohol as an infusion. The chapter on transfusions is not particularly well done, and it is regrettable that the semidirect method by means of a cannula is even described at all. The chapter on suturing blood vessels is very well done; in fact, it is probably more detailed than is necessary for a work of this kind. However, it is difficult to understand why, after such an elaborate description of arterial suture, nothing is said of the use of heparin in such cases to prevent thrombosis. Although the chapter on aneurysms is adequately described, nothing is given concerning the method of developing collaterals in aneurysms, either by means of the Matas compressor or by the newer method of treating the collaterals by means of blocking the sympathetic impulses. The chapter on causes of cicatricial contraction is particularly well done as are the chapters on plastic surgery in general. The remaining chapters are well done. The chapter on neurosurgery by Coleman is splendidly handled and leaves nothing to be desired. The volumes are valuable and should be in the library of every surgeon. It is unfortunate that more complete bibliographies are not given at the end of each chapter, as this would make the work even more valuable for the student.

Injuries of the Skull, Brain and Spinal Cord. Samuel Brock, M.D., Editor. Cloth. Pp. 632, with 63 illustrations. Baltimore, 1940, Williams and Wilkins Co. $7.

This monograph edited by Brock contains twenty-two chapters on different phases of the subject, each contributed by different authors who have been especially interested in the particular phase. Like most, if not all, monographs compiled in this manner, this book is well written and quite completely covers the subject of injuries of the skull, brain, and spinal cord. It is not permeated by the opinion or practices of one individual, but summarizes the literature and the personal experiences of the authors. This book is the most complete and best text in English on the subject.

Chapter 12, "Neurosis and Psychotic States"; chapter 13, "Head and Brain Injury"; and chapter 14, "Simulation (Malingering) in Relation to Injuries of the Skull, Brain and Spinal Cord," together cover approximately 125 pages, but only a few paragraphs are devoted to post-traumatic headache, vertigo, and diabetes insipidus.

Chapter 22, "The Medico-Legal Aspects of Injuries of the Skull, Brain and Spinal Cord," one would expect to treat medicolegal problems in aspects peculiar to injuries of these tissues. It is unnecessarily long, 54 pages, because it is not so limited.

The illustrations are well reproduced. Each chapter is accompanied with its own bibliography; many of these bibliographies are quite extensive.

For ready reference, this is the best book available on the subject.